Soil and Crop Science Society of Florida"

THE SOIL SCIENCE SOCIETY OF FLORIDA

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Seventh Annual Meeting of the Society
Gainesville
February 14, 15 and 16, 1946

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1946

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ACKNOWLEDGMENTS

It is indeed a pleasure for the Executive Committee to acknowledge the gratitude we all feel to President Tigert, to Dean Hume, and to Director Mowry for the generous use of University facilities which they have allowed us for holding these meetings in the Union Building, in the College of Agriculture and in Newell Hall; also to the staff of the Hotel Thomas for the fine hospitality extended to all of us throughout the period of our meetings here in Gainesville. It is the particular desire of the Committee most earnestly to thank Dr. Selman A. Waksman of Rutgers University, New Brunswick, New Jersey, for the special efforts we know he must have made to be with us and especially for the truly inspirational address he gave at our banquet meeting, a full look, as it were, into the depth and meaning of Science, as expressed by its antibiotical neophyte, and its very great possibilities for good in the future health and welfare of mankind.

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DEDICATION
DR. LEWIS RALPH JONES
1864-1945

Dr. Lewis Ralph Jones, born of sturdy, pioneer parents in Mentomen township of Fon du Lac County, Wisconsin, received his early education at Brandon, a village subsequently established near the homestead farm first purchased by his father, David Jones, as a government tract in 1828.

From 1883 to 1886, Dr. Jones attended Ripon College where he quickly found a rapidly deepening interest in the biological sciences, especially under the stimulating influence of Dr. C. D. Marsh, Professor of Chemistry and Biology at this institution at the time. However, it was while working under the influence of Professor Volney M. Spalding, following his entrance upon graduate work at the University of Michigan in 1886, that he turned definitely to the field of Plant Pathology, a decision that was influenced to no small degree by the late, great Dr. Erwin F. Smith, who was a brilliant graduate student and well advanced in his work in the Botany Department by the time Dr. Jones entered the Graduate School at Ann Arbor.

It is not possible, nor is it even necessary, to recite here in detail the brilliant achievements of Dr. Jones in his chosen field, either as a teacher or as a scientist, first at Mt. Morris Academy in Illinois and then at the University of Vermont where he served from 1889 to 1910. There are very considerable references in the literature to his great ability in the former capacity as well as his brilliant achievements in the latter. Many of the able writings by which he set forth his scientific findings in the laboratory will remain forever classical in the field of Plant Pathology.

In February of 1910 he went to the University of Wisconsin and began the monumental task of developing one of the finest departments of Plant Pathology to be found anywhere in the country. From it have emanated, through the years, some of the most brilliant workers that have appeared in this field.

Dr. Jones resigned the Chairmanship of the Department at Wisconsin in 1920 and retired from active service in 1935. However, he continued active for a number of years in many important public service assignments as committee man, trustee and counselor.

It might quite properly be said that his first important contact with Soil Science in Florida came in the Spring of 1927 when, as Chairman of the Executive Committee of the Tropical Plant Research Foundation with headquarters in Washington, D. C., and important projects in Cuba and elsewhere in the tropics, he visited the Everglades Experiment Station near Belle Glade. This was just as the first plant responses to some of the trace elements were being established on the raw peat soil of this great area, notably to copper, manganese and zinc.

His interest in what he saw on that visit was instantaneous and very, very keen; for he quickly realized the broad implications of these striking plant reactions which so plainly showed the very definite, though highly complicated relationships existing between the proper nutrition of plants—nutrition in the fullest sense of the word—and their general development and health. His interest in this work was so great that he always relished an opportunity to discuss it, especially after the work with trace elements

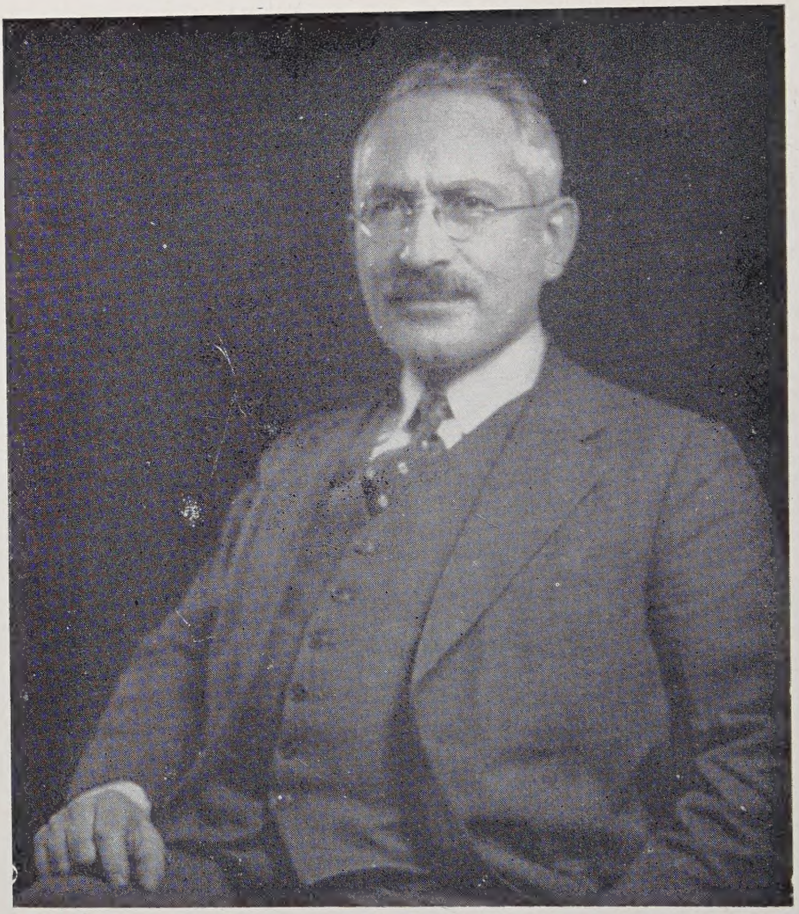
DR. LEWIS RALPH JONES
1864—1945

had extended from the organic soils of the Everglades out onto the mineral soils in practically all parts of the State for some crops on some soils in one section and for others in another.

Dr. Jones became a charter member of the Society in 1939 and never missed an opportunity to attend the meetings. In fact, he attended the 1944 sessions which were held in Orlando, and found much interest in the varied papers and in the discussions that followed.

The Florida sunset of March 31, 1945, proved to be the sunset of his life, for he died during the night of that day, peacefully, and surely with the consciousness of a full life, well lived. As has been so well said by some of his closest associates in his chosen field, "He will be long remembered for his leadership in Science and his example in life."

Robert V. Allison



DR. SELMAN A. WAKSMAN

GUEST SPEAKER

Due to the delay that has been experienced in the publication of this volume of the Proceedings, it is possible to conjecture that the Science of Antibiotics has progressed much faster and much farther, even during this comparatively short period, than Dr. Waksman would have dared to hope at the time of his inspiring lecture. Certainly the great honors which have come to him in the meantime as a result of his truly fine achievements in pioneering this remarkably fertile field have been richly deserved; for it is doubtful if, in the entire history of Science, one individual has ever contributed so much, especially when it is recalled that he is offering, in addition to his own scientific accomplishments, all of his personal earnings from the manufacture of streptomycin for the establishment of a great institute for work in Microbiology which, under his personal direction, is certain to exert a tremendous influence on this field of study in the years to come.

SOIL MICROBES AND MEDICINE

DR. SELMAN A. WAKSMAN *

Mr. Chairman, President Tigert, Members of the Society and Guests: As Dr. Allison has just indicated, I am going to tell you of a new branch of science which has had its origin and has reached a high stage of development only within very recent years. It has its roots in the soil and its applications in human health. Had I been invited to address you on this subject the last time I met with you here in Gainesville, namely in 1940, it is highly doubtful whether I could have had much to say about it. As a matter of fact, the very name of this new field of work that I am about to tell you of here tonight did not exist at that time. Thus, a new science has been born and has made tremendous progress in this short period of five of six years since the occasion of my last visit with you.

May I go back a few years and trace for you the origin of this new science of ANTIBIOTICS. Only ten or twelve years ago it was hardly believed possible that the time would come when drugs could be used effectively for the treatment of the majority of infections and epidemics. You will recall that there was only one group of diseases for which an effective drug was known at that time, namely syphilis, and the drug or drugs were arsenicals. Although many efforts were made, following the classical work of Ehrlich, to find new chemicals for treating bacterial diseases, the medical and chemical professions were forced to conclude that no drugs may ever be found for treating bacterial diseases of man—that is, drugs which could be injected into the body that would destroy the germ causing the disease and thereby cure the patient. When the sulfa drugs were discovered about ten or twelve years ago, and their potentialities for curing various diseases fully established, there was no doubt at that time that a great discovery had been made. The feeling even developed that the time was coming when all human ailments could thus be treated. Unfortunately, the sulfa drugs were found to have many limitations. First of all, they were found to act quite effectively on some diseases but not at all on others; many people proved to be sensitive to these drugs; it was discovered that some bacterial strains may become resistant to them. The medical profession began to wonder: here the sulfa drugs have pointed a way; what now? Where are the new drugs to come from, drugs able to attack the other disease-producing germs resistant to sulfa compounds. What member of the medical profession would have thought at that time that it was to be the soil from which these new drugs would come that ultimately were to be used for combating the resistant diseases! And, so it is with the soil that my story begins.

The subject of my talk this evening, soils in relation to disease, is really not of recent origin. Its development, however, and its effective application are very recent, as I have just indicated. To trace the development and to fully understand the growth of the field of antibiotics, however, one must go back to the early days of bacteriology. But let me first define an antibiotic. According to its present concept, it is a substance

* Microbiologist, Rutgers University, New Brunswick, New Jersey.

produced by micro-organisms which has the capacity of killing or destroying bacteria or other disease-producing organisms. Some can do this not only in the test tube but also in the human or animal body and consequently may actually be utilized for treating human and animal infections.

Not one but four sources of information or types of effort actually have contributed to the birth and development of this new science, the results being based quite largely upon observation and experimentation.

The FIRST of these sources is to be found in the early days of bacteriology when it was learned that most of the diseases are caused by bacteria and other microscopic forms of life. The medical investigators of that time began to wonder what became of all germs that were continuously excreted by the human sufferers. Thus we know that a typhoid carrier can bring disease to a whole community by infesting the bread or the milk supply. What, then, becomes of the millions and millions of bacteria excreted by the thousands and thousands of patients suffering from pneumonia, diphtheria, typhoid, cholera, and many other infectious diseases. Sooner or later, these disease-producing organisms must find their way into the soil—what then becomes of them!

When the plate method for isolating and counting microbes was first developed by Robert Koch in 1881, the medical bacteriologists said, "Let us look into the soil and see how many of these disease-producing germs can survive in this complex environment. Perhaps, after all, the soil is the source of all our infections and epidemics." Since the source of these infections was not known at that time, they could only "take a shot in the dark." Even now, for example, we still do not know how polio is transmitted. The bacteriologist, therefore, began to examine the soil for the possible survival in it of germs capable of causing infections. Just imagine, if you will, what the life of the worker in the field would have been had it been discovered that the soil can serve as a carrier or a reservoir of infection of various disease-producing organisms. Therefore, during those early years, the soil was very carefully investigated for the presence of disease-producing bacteria. To the great amazement of the medical investigators of that time, the discovery was made and the fact fully established that disease-producing bacteria do not survive very long in the soil. Furthermore, it appeared that they rapidly die shortly after arriving in this strange medium, not so much because they cannot live there, but because of the presence in normal soil of some agent that either kills them or prevents their development. The conclusion was reached, therefore, that the soil cannot be considered as a source of infections, except for a very few minor ones. Unfortunately, these early investigators stopped there. They did not go on in search of a logical reason and try to find out the nature of the agents responsible for the destruction of the pathogenic germs, isolate such agents and utilize their activity for the treatment of human diseases.

The SECOND source of information contributing to the development of the science of antibiotics is to be found in the study of interaction among micro-organisms. The great bacteriologist, Pasteur, in some of his early experiments on anthrax infections, observed that when the sheep were inoculated with a contaminated culture of the anthrax organism, the animals did not die. He recognized that this was due to some effect that the "common" or non-disease producing bacteria exerted upon the anthrax

bacillus. Pasteur said prophetically that the time may come when we may try to control disease-producing germs by utilizing the activities of non-disease-producing organisms. A very great vision, but he did not follow it up himself. Although others did, several years later, the results were disappointing because the proper method of approach to this highly complex problem was not known at that time.

Then there was a THIRD source of information, one that may well be regarded as quite observational in character. Every bacteriologist, especially the soil bacteriologist, has observed, at one time or another, that in a contaminated culture of a bacterium on an agar plate, the bacterium is either killed outright or does not grow in a definitely normal fashion. To a medical bacteriologist, a pure culture of an organism is an absolute requirement for further investigation. As a matter of fact, among the very first lessons in bacteriology, one learns that in order to associate a certain organism with a given disease, it must first be isolated in pure culture. The soil bacteriologist, on the other hand, does not work exclusively with pure cultures, but more often deals with mixed populations, since the soil contains thousands of different organisms that are responsible for a wide variety of processes occurring every day in this complex medium. Consequently, the soil bacteriologist, as well as the medical bacteriologist, has often observed the appearance on the plate, of a ring or a clear zone around a colony of a fungus or a bacterium that happens to contaminate a culture of another bacterium. One such observation was made in England by Fleming in 1929. He had a culture of a common staphylococcus growing on an agar plate. This culture became contaminated by a common green mold (Penicillium); the colony of the mold was surrounded by a clear zone. Fleming became curious. He wondered whether this was due to the fact that the mold killed the bacteria. On careful study, he found that the clear zone around the rapidly growing mold was due to the destruction of the bacteria. He named the substance produced by the mold "penicillin", and suggested that the time may come when this phenomenon will be utilized in combating disease-producing bacteria. He, himself, did not attempt to follow up his own suggestion and penicillin remained dormant for another twelve years.

The FOURTH source of information that led to the development of the science of antibiotics must be credited to the work of the soil bacteriologist, who has been accustomed to studying the interactions of different micro-organisms growing in this complex environment. He began to wonder how these organisms were able to live together in association; to what extent they were dependent upon one another; and how they were able to compete among themselves for food. He continued to wonder why certain bacteria, once introduced into a soil, do not become established and thrive but quite rapidly die out instead. He also began to study the antagonistic effects of one soil organism upon another.

It required the synthesizing mind of an investigator with a keen imagination to bring these loose ends together and build a new science. The first attempt to do this was made by Dubos. Trained in a Soil Bacteriological Laboratory and working in a Medical Institute he had the training and the viewpoint required for this complex task. After many efforts, he succeeded in isolating from the soil an organism, in this case a spore-forming aerobic bacillus, which produced a substance destructive to many bacteria.

This substance, named gramicidin, had the capacity to kill various pneumococci, staphylococci, and other gram-positive bacteria. Furthermore, it was active not only in the test tube but also in the animal body. It appeared to have all the desirable properties of a chemotherapeutic agent. More important, still, it pointed a way to the isolation of new antibacterial agents.

Although the substance thus isolated (later found to be a part of a complex of substances designated as tyrothricin) was immediately recognized as the result of a long-hoped-for method of approach to a difficult problem, it found only limited application as a chemotherapeutic agent. However, this work stimulated a tremendous amount of research. Among the research institutions which almost immediately became interested in this subject were our own Soil Microbiology Laboratory at the New Jersey Agricultural Experiment Station, and that at Oxford University in England. Work in both of these laboratories started almost simultaneously late in 1939. The war was on. Everybody was searching for new agents for the purpose of combating new diseases and epidemics. The First World War brought us the Spanish influenza, and gaseous gangrene. What diseases were to come as a result of the new war? Even bacteriological warfare was whispered about. What consequences were to follow? New agents for combating such possible infections were urgently needed.

The Oxford group became interested both in bacteria and fungi as producers of antibacterial substances. They soon discovered that penicillin was really the ideal agent. It was active against many bacteria; it was active both in the test tube and in the animal body; and it was not toxic to animals. Furthermore, it could easily be extracted from the culture filtrate of the mold, and concentrated. Finally, it was found that it could be used in the human body for the treatment of diseases. There is no need for dwelling further upon the subject of penicillin. It is now history. It is sufficient to say that during World War II it saved thousands of lives. Certainly it has proven itself one of the greatest scientific discoveries made during the war period.

Now in addition to those diseases that respond to sulfa drugs and to penicillin, there are many others that do not respond at all or only to a very limited extent to either treatment. These are the diseases caused by gram-negative bacteria and certain others, notably tuberculosis. The gram-negative bacteria cause a variety of diseases, ranging from urinary infections, typhoid, tularemia, cholera, plague and many others. Neither the sulfa drugs nor penicillin have an effect upon these bacteria nor upon the tuberculosis organism. Our work at the New Jersey Agricultural Experiment Station, starting late in 1939 as it did, was gradually concentrated upon the isolation of chemical agents, now commonly called antibiotics, which could prove themselves active against these bacteria.

A large number of bacteria, fungi and actinomycetes were isolated from the soil. In turn, several distinct substances were isolated from these organisms and studied in detail. Gradually our attention was centered more and more upon the actinomycetes, a group of organisms which we have been studying in New Jersey since 1915, a great many of which were especially well known to us.

Figure 1.—Isolation of Antibiotic Substances.

1. *Isolation of antagonistic organisms*

Soils, composts, manures and sewage as source materials.

(a) Common agar media used, colonies isolated at random from plates.

(b) Washed agar-bacterial media; zone-forming or other colonies picked.

(c) Low dilutions used; colonies producing inhibition of other organisms picked.

(d) Special selective media used.

2. *Testing of isolated colonies*

(a) Streak method; against gram-positive and gram-negative test bacteria.

(b) Removal of agar plugs from plates in which antagonist is growing for test of antibiotics.

(c) Liquid media containing bacterial suspension inoculated with antagonist.

(d) Agar media inoculated with test culture, followed by inoculation with antagonist.

3. *Production of antibiotic substances*

(a) Synthetic and organic media used.

(b) Filtrate tested by convenient method.

(c) Study of surface vs. submerged culture.

4. *Antibacterial spectrum and general properties of type substance produced*

(a) Determination of bacteriastatic spectrum by suitable methods.

(b) Chemical and physical properties of crude preparation.

(c) Pharmacological properties and *in vivo* activity.

5. *Recognition of type substance on basis of antibacterial properties*

(a) Bacteria:
Pyocyanase, tyrothricin, or subtilin type.

(b) Fungi:
Penicillin, gliotoxin, clavacin, penicillic acid type.

(c) Actinomycetes:
Actinomycin, streptothricin, streptomycin type.

6. *Isolation of antibiotic substance*

(a) Use of organic solvents.

(b) Adsorption on charcoal, and removal by acid solutions or by solvents.

(c) Other methods of isolation.

7. *Isolated antibiotic: antibacterial, physical, chemical, and pharmacological properties*

8. *Chemotherapeutic use*

I should like to present a series of slides illustrating our methods of procedure in the isolation of antagonistic organisms from soils or from composts and the consequent extraction of antibiotic substances from cultures of these organisms.

In general eight distinct steps are involved. These are illustrated in Figure 1. Outlined in this manner these steps illustrate in a much better way than can be described in words the tremendous amount of labor involved. We have now isolated and tested some 10,000 cultures of fungi and actinomycetes.

Once a desirable organism has been isolated (Figure 2), we test its activity against various bacteria. Then we try to develop a suitable method and proper conditions for the production of the active substance on a large scale. Next we are concerned with the development of suitable methods for the isolation of the substance from the medium in which it has been produced by the organism.

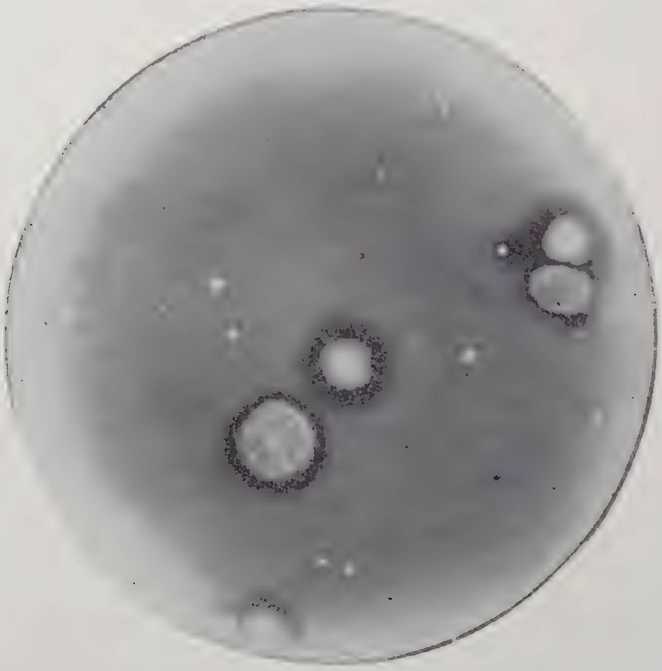


Figure 2.—Development of antagonistic organisms on the bacterial-agar plate. From Waksman and Horning—in Mycologia.

During the process of isolation, we use only biological methods based upon the antibacterial properties of the substance in question for testing its activity. This involves the agar streak method (Figure 3), the agar diffusion or "cup" method (Figure 4) and others. We are still dealing, of course, with a substance of unknown chemical properties.

By using the selective inhibition of one of these unknown substances upon several test bacteria, we are able to gain an idea of the bacteriostatic

Figure 3.—Streak method. From Waksman and Woodruff.—
Jour. Bact.

Figure 4.—Agar cup method.

spectrum of the substance. For a more complete spectrum, it is necessary to use a much larger number of organisms.

A typical spectrum of an antibiotic substance is shown in Table 1. Once the substance has been extracted from the medium and concentrated, a study is made of its toxicity. The first substance that we isolated in New Jersey, which we designated as actinomycin, proved to be highly toxic to animals. The second substance, isolated from certain fungi and designated as clavacin, also was quite toxic. A third substance, also isolated from fungi, chaetomin, was not very toxic. Neither was it active in the animal body.

TABLE 1.—BACTERIOSTATIC SPECTRA OF STREPTOMYCIN AND PENICILLIN.

Organism	Streptomycin *	Penicillin **
Bacillus anthracis	0.375	1.0
B. mycoides	0.1-3.8	—
B. subtilis	0.12-1.0	—
Brucella abortus	0.5-3.75	500
Br. melitensis	0.5	> 1,000
Cl. tetani	> 104	1.0
Corynebacterium diphtheriae	0.375-3.75	8.0
Eberthella typhi	1.0-37.5	100
Escherichia coli	0.3-3.75	> 1,000
Hemophilus influenzae	1.56-5.0	—
H. pertussis	1.25-3.0	—
K. pneumoniae	0.625-8.0	> 1,000
M. tuberculosis var. *hominis*	0.15	> 1,000
Neisseria gonorrhoeae	5.0	0.5
Pasteurella pestis	0.75-1.5	1,000
P. tularensis	0.15-0.3	—
Proteus vulgaris	0.4-3.0	250
Pseudomonas aeruginosa	2.5-25.0	> 1,000
Salmonella enteritidis	0.5	—
S. schottmülleri	2.0	—
Shigella paradysenteriae	0.25-3.75	500
Staphylococcus aureus	0.5-> 16.0	1.0
Streptococcus faecalis	50.0	—
S. hemolyticus	2.0-> 16.0	—
S. viridans	> 16	1.5-250
Vibrio comma	6.0-37.5	> 1,000
Actinomyces bovis	3.75	1.0

* Micrograms of pure streptomycin per 1 ml. of suitable medium required to inhibit growth. From paper by Waksman and Schatz (Jour. Amer. Pharm. Assoc., November 1945).

** Data reported on basis of micrograms of crude penicillin required for complete inhibition. From Abraham, Chain, Fletcher, Florey, Gardner, Heatley and Jennings (Lancet, 1941). Note: 1 microgram of this particular penicillin preparation is equivalent to about 0.01 mgm. of pure penicillin.

You can thus see that a worker in this field lets himself in for a series of disappointments in undertaking a study of antibiotic substances. No wonder, therefore, for out of nearly 100 substances already isolated and described, some of which have even been crystallized and chemically defined, only three or four have ever found practical application.

Thus, when we isolated streptothricin in 1942, we thought that we had obtained a highly desirable substance. It was soluble in water; it was not

very toxic; and it was active against gram-negative bacteria. Unfortunately, upon more detailed study, it was found to have a delayed toxic effect upon experimental animals and thus was automatically curtailed in its usefulness.

Finally, in 1943, we isolated streptomycin. The organism from which it was obtained is a typical soil actinomyces, *Streptomyces griseus* (Figure 5). Fortunately, this substance was found to have all the desirable properties of streptothricin but possessed a much lower toxicity to animals. Furthermore, it was found to be active against a large variety of bacteria not affected by the sulfa drugs or by penicillin. Because of these facts it attracted immediate attention. Within two years after its isolation streptomycin was being produced on a large scale, and was finding application in the treatment of a variety of infections. Its action upon tuberculosis is still uncertain. It is active, however, upon *Mycobacterium tuberculosis* in the test tube (Figure 6) and in experimental animals.

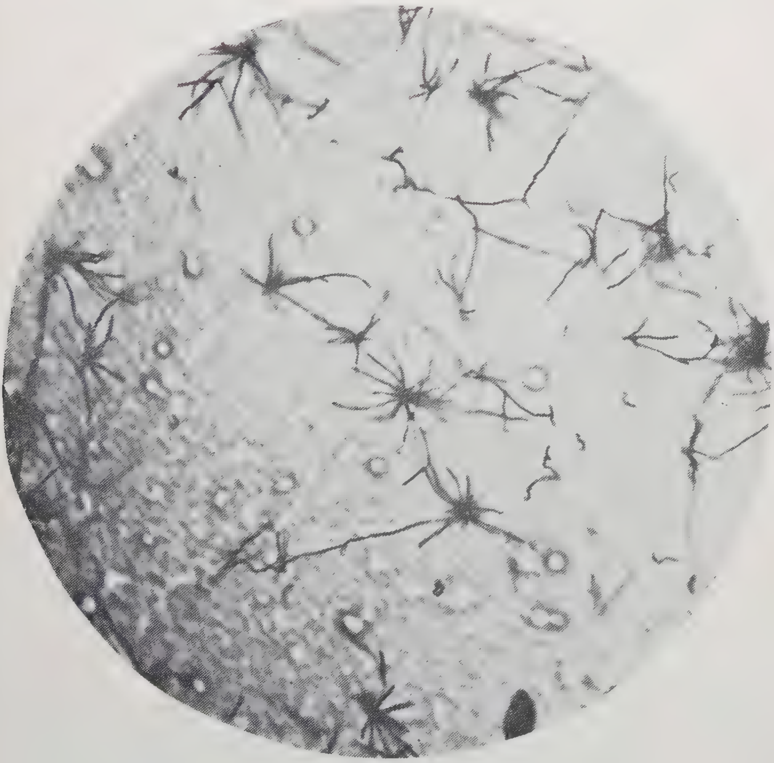


Figure 5.—*Streptomyces griseus* 305×. Streptomycin-producing strain.

Summarization. In discussing the relation of soils to medicine through the medium of antibiotics which have been or may be isolated from them in the future, we are dealing with a field of science which hardly existed five or six years ago. Although this brand new field of antibiotics has come so rapidly to the front and already has made some very spectacular

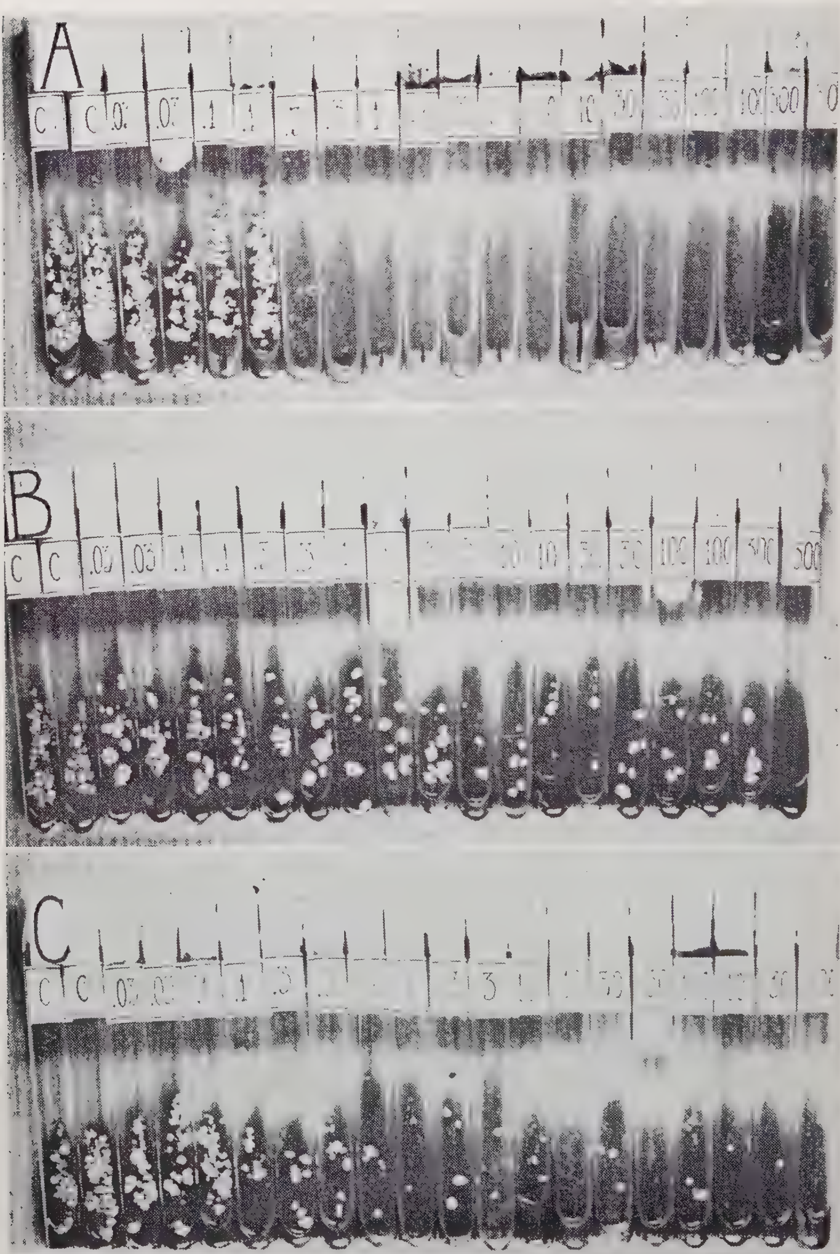


Figure 6.—The bacteriostatic and bactericidal action of streptomycin upon a human strain (H37) of *M. tuberculosis;* the figures on the tubes give the units of streptomycin, C being the control.

A. Bacteriostatic action.
B. Bactericidal action, three days.
C. Bactericidal action, seven days.

gains, how far it can still go remains entirely in the lap of the gods. There are many diseases against which we not only have found no cure but not even a faint promise of a cure. I am not speaking of diseases like cancer or rheumatic fever, the causative agents of which are still not fully understood. I am referring particularly to highly infectious diseases, such as virus infections. Even diseases like tuberculosis and undulant fever should not be considered as conquered. Knowing as we now do how much progress has been made in the development of penicillin, when we have, at present, strains of organisms which produce at least one hundred times greater activity than the original culture of Fleming, one can not help but wonder how far we may go in finding still other antibiotics which will have greater power and a much more varied capacity than any which have been discovered in the past to destroy even those disease-producing agents which are, as yet, but little understood.

SEMINAR: SOIL SURVEY AND PLANT BREEDING
Newell Hall, Thursday, February 14, 1946
8:00 P. M.

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A NATURAL GROUPING OF FLORIDA SOILS

J. R. Henderson *

"Grouping" is the placing together of two or more similar objects. The objects within a group may be similar in many or in only a few characteristics. If a small number of characteristics are considered only a few groups will be recognized, each group will contain a great number of units, and the precision with which the groups may be described is limited. On the other hand, if a great number of characteristics are taken into consideration, many groups will be recognized, each group will be made up of only a few individuals, and the groups may be defined rather precisely. In any grouping it is necessary to consider all the various characteristics of the objects to be grouped, and to determine which characteristics are to be used as a basis for the grouping.

Since the initiation of the soil survey program of the United States Department of Agriculture in 1899, many attempts have been made at grouping soils into simple classes. The purposes and methods have been quite varied and, of necessity, so have the results. However, the approach to the problem generally has been along one or the other of two lines: the soils have been grouped according to similarities in their *characteristics* or they have been grouped on the basis of recognized or assumed similarities in *adapted uses, yields* or *management requirements.* The former is referred to as *natural* or *scientific* soil grouping and the latter is called *practical* soil grouping. Either should be preceded by a detailed consideration of all the various internal and external characteristics of each individual soil.

The purpose of this paper is: (1) To enumerate the characteristics that should be considered in the differentiation of individual soils under Florida conditions, (2) To point out some of the possibilities for natural groupings at various levels of generalization, and (3) To discuss some of the problems involved in the evaluation of soils in practical terms.

CHARACTERISTICS TO BE CONSIDERED IN THE DIFFERENTIATION OF INDIVIDUAL SOILS

The soil type and the soil phase are generally regarded as the ultimate units in a natural classification of soils. A soil type is defined as "a soil that is relatively uniform in all of its profile characteristics" and a soil phase as "that part of the soil type having minor variations in characteristics used in soil classification from the characteristics normal

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for the type." Since soil profile characteristics are partly the result of the environment, a given soil type should be confined to fairly uniform external conditions. Soil classification under Florida conditions which result in the recognition of such units should be based on a consideration of the following characteristics:

1. Kind of soil—whether mineral or organic.
2. Number of horizons.
3. Color of the horizons.
4. Texture of the horizons.
5. Consistence of the horizons.
6. Reaction of the horizons.
7. Chemical composition of the horizons.[1]
8. Thickness of the horizons.
9. Organic matter content and distribution.
10. Origin and nature of the parent material.
11. Depth and character of the underlying formations.
12. Drainage.
13. Slope.
14. Stoniness.
15. Native vegetation.

Many of these characteristics are interrelated in such a way that giving expression to one also gives expression to one or more of the others. For instance, organic matter content, chemical composition and drainage conditions are, within limits, indicated by color. Moreover, texture and consistence are so closely related that certain textural characteristics always indicate definite kinds of consistence. Thus, any grouping based upon only a few characteristics may indicate certain conditions in regard to others.

The importance of each characteristic may vary considerably among different soils but should be comparatively constant for any specific soil. Furthermore, certain properties of any soil type may be highly significant from the standpoint of soil classification but, in the light of current knowledge, may have no special weight in the determination of crop adaptations, yields or management requirements. On the other hand, some properties may be very important in relation to the practical problems of soil utilization but be of only minor significance from the standpoint of scientific soil classification.

Summarizing: The soil type and the soil phase are the ultimate units in scientific soil classification. A specific soil type, or soil phase, represents a rather definite combination of a great number of internal and external characteristics. The relative importance of the several characteristics may vary among individual soils. Two or more individual soils may be considered almost identical from the standpoint of practical agriculture, even though they are definitely different as regards their natural characteristics.

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[1] Insofar as it is possible to ascertain by simple tests and correlation with observable physical features.

NATURAL GROUPINGS OF SOILS

Up to the present time several hundred soil types and phases have been recognized in Florida, and, as the soil survey program is extended, perhaps many more will be encountered. It is obvious that grouping of the individual soils is necessary if information regarding them is to be conveyed to those not trained in soils. The feasibility of grouping the soils on the basis of their own characteristics is apparent.

Natural groupings may be on the basis of any number of characteristics less than the number used in recognition of the individuals. In general, as many characteristics as the desired simplification will permit should be used. Groupings may be made on a statewide, sectional or county basis. Obviously a statewide grouping would be based on a smaller number of characteristics than a sectional grouping and a sectional grouping on a smaller number than the grouping for a county. Moreover, the characteristics used for one section or county need not be the same as those used for another. A county grouping should reflect the important soil differences in that area. If the groupings are to have practical significance they should be based on differences known to effect land use. Always, the groups should be defined in soil terms rather than in land use terms. This does not mean that land-use relationships should not be stated when they are known or can be ascertained.

EVALUATION OF SOILS IN TERMS OF LAND USE

The demand for practical knowledge concerning soils has forced soils men to go beyond the bounds of scientific soil classification. Several methods of rating soils have been attempted. In these, especially under Florida conditions, the problems encountered have been numerous and somewhat perplexing. The task is complicated by the fact that land use relationships are determined in part by forces outside the soil. Schemes for soil evaluation have sought to point out one or more of the following: (1) adapted uses, (2) crop yields and (3) management requirements. Some of the problems encountered in each method will be discussed briefly.

Determining Adapted Uses of Soils

The suitability of various individual soils for different uses or for different crops is only partially determined by soil characteristics. Additional factors must be considered. In Florida, local variations in climate, water supply and seasonal conditions of water table each may have an important bearing on land use.

Several examples of the effects of these additional factors will be cited. Norfolk fine sand, in the warmer sections is highly desirable for the production of citrus, in other sections it is used for the production of early watermelons, whereas in still others it is considered unsuitable for the crops that are grown under climatic conditions there. Recommended uses for Leon fine sand are usually for forestry or grazing, but in some sections with suitable climate and a good supply of flowing artesian water, this soil is well suited for the winter production of a wide variety of vegetables and other horticultural crops. The Arzell and Charlotte soils of southern Florida are inherently very poor soils and have a high water

table during most of the year. Yet during the dry season of the fall and winter they may be used profitably for the production of vegetables with very little expenditure for water control.

Thus, it is obvious that soil characteristics alone do not determine crop adaptations.

Rating Soils on the Basis of Crop Yields

Crop yields are determined largely by soil characteristics, climate and management. For a given soil type in a local area, the climatic and soil factors are largely eliminated, so that variations in crop yields on that soil should be due to variations in management. Realization of this fact has lead to estimation of yields of each of the various crops under several different combinations of specified management practices.

Yield data are generally referred to a standard index of 100. This standard index represents the productivity, without the use of fertilizers and amendments, of the more productive soils of that region in the United States, where the specified crop is most extensively grown. An index of 50 indicates that the soil in question is about half as productive as the soil with the standard index. Such indexes are called productivity ratings.

Productivity ratings are determined for three different conditions of management: (1) without special practices to maintain or increase soil productivity; (2) the present prevailing practices of soil management; (3) the best practices of soil management.

The use of similar productivity ratings under Florida conditions is handicapped due to several reasons: (1) Past management history is often more outstanding in the determination of yields than is present management. (2) It is not easy to determine the prevailing soil management practices for certain crops. (3) Harvested yields are often determined by market conditions and obtaining reliable data is difficult. (4) The best management practices are not known for all soils.

Grouping Soils on the Basis of Management Requirements

Within recent years, grouping soils according to management requirements has been attempted. In the early work this type of grouping, known as "Land-Use Capability" classification, was applied successfully in areas in which prevention of erosion was recognized as the most important single soil management problem. More recently land-use capability classification has been extended to areas of well drained porous sandy soils, on which erosion is not a problem, and to areas of poorly drained soils where drainage is recognized as the primary problem of soil management. Thus, at present, land use capability classification is being applied to each of three distinct soil conditions.

In each kind of problem area the soils are placed in eight land classes, of which the first four are considered suitable for cultivation and the last four are considered unsuitable for cultivation. The eight classes of land are defined as follows:

Class I—Land suitable for permanent cultivation without special practices.

Class II—Land suitable for permanent cultivation with simple practices.

Class III—Land suitable for permanent cultivation with intensive practices.

Class IV—Land suitable for only occasional or limited cultivation.

Class V—Land not suitable for cultivation but suitable for permanent vegetation that may be used for grazing or for woodland without any special restrictions.

Class VI—Land not suitable for cultivation but suitable for permanent vegetation that can be used for grazing or for woodland, with moderate restrictions.

Class VII—Land not suitable for cultivation and requiring severe restrictions if used for pasture or woodland.

Class VIII—Land not suitable for cultivation or for the production of useful, permanent vegetation that may be harvested under grazing or woodland use.

Complications which have arisen in areas where all three soil conditions are present has lead to the recognition of subclasses for each kind of major management problem. This procedure often results in the recognition of natural soil groups that could be more easily defined in terms of their characteristics than in terms of their management requirements. Moreover, this type of classification infers that all problems of management have already been solved.

SUMMARY AND CONCLUSIONS

Modern techniques in soil surveying result in the recognition of many individual soils each of which possesses a peculiar combination of soil characteristics. If soils information is to be extended to those not trained in the subject the individual soils must be grouped. The individual soils may be grouped on the basis of one or more characteristics into *natural* soil groups.

There is a popular demand for a practical grouping of soils. Attempts have been made at practical groupings in terms of adapted uses, crop yields or management requirements. However, the results have not been satisfactory under Florida conditions.

It appears that great progress can be made if natural instead of practical soil groupings are developed and information regarding use and management be tied to these as it becomes available.

PLANT BREEDING IN RELATION TO SOIL FERTILITY AND CLIMATE

Dr. Fred H. Hull *

This opportunity to discuss plant breeding in relation to soil fertility and climate with a group of soil specialists has been accepted gladly because I think the direction of plant breeding may sometimes depend on progress in soil science.

With continued advances in the science of soil fertility and fertilizer practice, and with the development of better soil improvement crops such as the lupine, we may expect the level of fertility of crop lands in Florida to be raised appreciably. This may be particularly true of lands growing corn, peanuts, oats and the grazing crops. Natural fertility is low and a minimum of fertilizer is used.

Soil fertility is measured finally by crop production, I suppose, provided that a well adapted variety of the crop is available. There is a widespread belief that peanuts often fail to make profitable responses to fertilizer. And it is reported that additional responses of corn in Florida to higher rates of fertilizer are sometimes disappointing. Explanations of these failures are not readily apparent nor simple. I am led first to consider that the peanut is not a thoroughly domesticated plant. It will persist for some time in sod land. The peanut is a poor land crop. We may have somewhat of a parallel case in the range cow or the range hog. These animals may survive and reproduce on the range better than improved, pure breeds. But in the dairy barn or feed lot, performance of purebreds is far superior to that of range animals. The latter seem unable to respond fully to abundant nutrition.

We may question, of course, whether or not the turning under of a heavy leguminous crop and balancing the nitrogen with potash and phosphate will always provide abundant nutrition in the full sense to a following crop. Other elements may be deficient or out of balance initially or may be made so by heavy rainfall. How serious this general problem is and how rapidly the soil chemist may solve it, I do not know. My interest is in the burden of unsolved residue which presumably, will fall on the plant breeder. If this problem is of slight importance there is still the question of drought which may be serious where a high fertility level is built up on light land and a thick planting of the crop is made. Relation of corn production to climatic factors must be quite different when fertilizer rate and thickness of planting are both doubled.

Most of the corn grown in Florida has been here a long time and has perhaps achieved some degree of adaptation to prevailing climate, soil, and soil management. If now we begin looking for a corn which will produce efficiently after lupines with heavy fertilization and thick planting will we find it among the varieties and hybrids developed in the older practice? Or how fast may we go in developing the desired type? The question of how well corn may respond to high rates of nitrogen, potassium

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and phosphorus which is being currently investigated at various points in the South might be varied to ask at what levels of these and other elements might corn breeding operations best be done? No one, of course, has any definite answers to these questions. I shall devote my remaining discussion to some of the factors which may bear on them.

Stringfield and Salter (6) tested several local corn varieties and some corn hybrids in Ohio on fertility levels ranging from no treatment to 16 tons of stable manure plus 800 pounds of fertilizer per acre. They found differential varietal response to fertility levels in 2 of 5 seasons. Differential response of varieties to seasons was highly significant and much greater than that to fertility levels. Some varieties were superior in the dry seasons—not so much so in wet seasons. Other varieties were definitely "good season" performers.

Smith (5) and Lyness (4) separately tested different strains of corn on different levels of phosphorus. Each one found marked differences among lines on low phosphorus. Smith found lesser differences on low nitrogen. Efficient lines on low phosphorus had greater proportions of secondary to primary roots. Harvey (1) found significant differences in responses of corn hybrids and inbred lines to ammonium and nitrate nitrogen in nutrient solution cultures. Similar work has shown inherited differences in nutritional requirements among different pure strains of tomatoes, and of other crop plants. "Whitebud" of corn which has been corrected in Florida by application of zinc salts was much more severe in some varieties of corn than in others. The more susceptible varieties were those developed on the more fertile soils.

This brief review supports the general belief that crop plants may be bred for adaptations to variations in available nutrient elements and to variations in climatic factors. A vast amount of data from cooperative tests of experimental hybrids by state and federal agencies shows also a considerable amount of differential response of hybrids to conditions in different states at the same latitude.

Let us look now at the general picture of corn breeding experience for indications of how rapidly we may breed corn for adaptation and how far the process may be carried.

Most of the work of developing the highly domesticated corn plant with its unique structure, the ear, was done in past centuries. Controlled breeding experiments were begun 50 years ago when Hopkins at the Illinois Experiment Station introduced his ear-row breeding plan. One novel feature was the planting of a row of corn with seed taken from a single ear. Ear-row selection was the selection of a few of the more productive of 100 such ear rows.

A few years after ear-row breeding began the still further complication of growing ear-rows from self-fertilized plants was started. This new practice eventually led to hybrid corn which now grows on about 2/3 of the corn acreage of the United States. The realized yield improvement from hybrid corn is estimated at about 20%, although considerably higher gains have been obtained in experimental plots. Such gains are obtained with only a few certain combinations of inbred lines. Many combinations are actually less productive than the original varieties from which the inbred lines were derived.

Among some corn breeders there has been the expectation that a considerable advance in yield of hybrids would appear when a new cycle of inbred lines had been derived from crosses of the best lines of the first cycle. It is now fairly clear that this expectation is not to be realized beyond a very limited extent which is truly disappointing if no alternative can be found.

Various explanations have been suggested for the apparent halt in progress of developing still higher yielding hybrid corn. One is that a close approach to a physiological ceiling has been realized in the better hybrids now in hand. Another is that the later cycles of work have been too limited in extent.

A third possible explanation which has been of great interest to me recently is that our breeding operations have been designed on a misconception of the genetic nature of hybrid vigor in corn.

If we must accept either of the first two explanations, we must be prepared to be content with little more than 20% improvement of corn yield in the South by the use of hybrid seed. The extensive work of the past 20 years on development of hybrid corn in the main corn belt area is not likely to be equalled anywhere in the South for a long time. If we may find the third explanation correct. our expectations for improvement of corn yield may be considerably greater.

Behavior of corn yield in breeding experiments has been somewhat enigmatic. First of all the extensive and long-continued, ear-row selections effected hardly any improvement of yield at all. In the two succeeding decades selection within and among self-fertilized lines based both on appearance of the lines and on hybrid performance effected an improvement of 20% in yield. This not inconsiderable result was obtained early with the first cycle of inbred lines. Later work with second and even third cycles of inbred lines has provided little or no further improvement of yield. In contrast second and third cycle lines are frequently very great improvements over lines of the first cycle in many other desirable characteristics. We recall too that the Illinois ear-row selection experiments were very effective in modifying oil and protein content of the seed and morphology of the plant.

In 1935 we began at the Florida Station with a cross of the large, late field variety, Tuxpan, and the small, early sweet variety, Golden Cross Bantam. Selection was practiced at approximately the rate of the best plant in 100 for the most leaves or nodes on the stalk. The astounding result, after four generations, was a new strain with an average of 20½ leaves or nodes above ground. The average for original stock was 13. No plant with 20 leaves was observed among some 1300 of the original stock. But by measuring the variation statistically of several hundred of the original plants it was estimated that one with 20 nodes might have been expected once among some 10,000,000. Thus the gain effected by growing about ¼ acre of corn each year for four years was approximately that of growing 3000 acres the first year and selecting the best single plant. The principle involved here is roughly analagous to dilution technic. A laboratory utensil is rinsed 3 times successively with 10 c.c. each time to obtain the same dilution of contamination with 30 c.c. as would be done by 1000 c.c. in a single rinsing.

This multiplicative principle must have been understood, at least in part, by early operators of ear-row selection. Failure of the ear-row method and subsequent success of hybrid corn for improvement of so important a character as corn yield have probably caused undue emphasis to be given to inbreeding and too little to recurrent selection as plant breeding tools.

Selection for high oil on the ear-row plan continued for 28 years by the Illinois Experiment Station achieved a result equivalent to improving yield 120%. This comparison is made with due allowance for initial genetic variability of the respective characters. Slightly less striking results were obtained in separate operations for low oil, and for high and low protein. Our result with high number of nodes on the stalk is equivalent to about a 50% improvement of yield. Amazingly enough, there was no apparent loss of genetic variability during any of these selection operations. Selection could have been continued further with no lessening of effect.

I must emphasize too that if we should go into a field of corn of the original stock of any of these selection operations to look for a single plant equal to the final product, we might not find such a plant in thousands or even many millions of acres. It is hardly too much to say that something really new was produced. But if we should look in a field of one of the well adapted old type varieties for a single plant equal in yield to the best hybrid so far developed, we would probably find it among the first 1000 plants; certainly in the first acre. This is true in spite of the much greater effort expended on yield of corn. Of course yield is more dependent on environmental variations and more difficult to measure but I think we are still forced to conclude that its response to breeding effort is unique and slow. I think too that we must learn how to make recurrent selection work with yield of corn if we are to go far in developing efficient nutritional complexes for the higher levels of fertility which good soil management must provide.

In the latter part of the 19th century there developed among biologists a great interest in continuous or recurrent selection as a possible explanation of the remarkable variations and adaptations of plants and animals. Failure of ear-row selection with corn yield may have dampened enthusiasm for that explanation. Success of hybrid corn possibly gave emphasis to the theory that isolation and inbreeding are necessary for effective selection, as they very probably are. More recently Gossett in Ireland and Fisher in England, the two statisticians who developed the "Analysis of Variance," have re-examined the Illinois ear-row data with oil and protein. They pointed out the remarkable nature of results obtained that I have already noted. Fisher says with respect to the multiplicative aspect of continuous selection, that it "—is a mechanism for generating improbability of very high order."

Still more recently I have undertaken an analysis of some of the data on yield of inbred lines and hybrids of corn as published by various workers or as accumulated from cooperative tests of State Experiment Stations and the U.S.D.A. Here another seemingly enigmatic feature of corn yield has appeared. If we study the several crosses of a weak inbred line with a number of other lines we find on the average, that where the

other line is weak the hybrid is weak; also that where the other line is strong the hybrid is strong. Among the crosses of a line of medium vigor the same tendency is clear but not so strong. Among the crosses of one of the strongest lines the tendency is hardly evident at all or in extreme cases may appear slightly reversed. The enigmatic feature of these results is not that the tendency decreases as we improve the common parent of a group of hybrids, but that the tendency disappears when the common parent is still a weak inbred line with yield hardly one-half that of an average hybrid.

In analogy, consider a variable herd of cows. If the herd sire is weak and nondescript the calves are variable with merit dependent largely on that of the dams. The sire is not prepotent. If the herd sire is very good, the calves are much more uniform. Those from the poorer cows are not much poorer than those from the better cows. The sire is prepotent. A completely prepotent bull with offspring from poor cows just as good as offspring from good cows would be a very excellent individual. No one has seen an animal so good.

In corn we have apparently a number of inbred lines completely prepotent for high yield. These prepotent lines, while the best we have, are quite weak and unproductive in comparison with ordinary corn.

On current theory of the genetics of hybrid vigor in corn the most prepotent inbred line should be the equal of the best hybrid in vigor and yield. This line would not be easily obtained because of genetic linkage of favorable with unfavorable factors, but steady progress towards it by current breeding methods should be possible. A close approach to the goal of a pure line in which all of the more favorable factors are fixed would probably make hybrid seed corn with its renewal each year unnecessary. On this theory hybridity is not truly fundamental for high vigor and yield.

If now we adopt the alternative theory that hybridity is fundamental to high vigor and yield all of the enigma of corn breeding experience with yield seems to disappear. Ear-row selection failed primarily because after each ear-row test the best individual ears were taken from the selected ear-rows. The best individual ears were from the most hybrid plants. In them excellence was due not to higher than average concentration of favorable factors but to a greater than average concentration of hybridity —matching of each more favorable factor with a less favorable mate. Such selection favors the less favorable almost as much as the more favorable factor.

Similarly, second cycles of inbred lines from the parents of the best hybrids in the first cycle failed because the best hybrids of the first cycle were not those with higher concentrations of favorable factors. They were the most hybrid ones, with no greater proportions of more favorable factors than found in original stock. Hybrid corn has succeeded up to a point with certain rare combinations having more than average hybridity. Such rare combinations when once found are repeatable by recrossing the pure parent lines.

The fact that a strong inbred line is likely to combine equally as well with a weak line as with another strong line, may be explained on present theory by the greater expectation of hybridity in the cross of strong $\times$ weak.

Other hitherto unexplained details which now become clear hardly need be enumerated here.

I must emphasize that available evidence is not sufficient for definite proof that hybridity is fundamental for high yield of corn. It is simply that this theory appears more plausible than any other. It leaves no unexplained residue so far as present evidence goes. On this basis we must, for the present, consider revision of corn breeding technic towards the goal of the greatest degree of hybridity and abandon the goal of the greatest concentration of favorable factors. How this may be done has been fully described (2), for those regions where hybrid seed corn is commercially feasible.

Where hybrid seed corn is not feasible it would seem well to try ear-row selection again or some modification as the one proposed by Jenkins (3). In such operations secondary selection based on individual appearance must be avoided as strictly as possible.

The newly proposed breeding plan (2) to develop a superior hybrid allows maximum utilization of the multiplicative principle in recurrent selection. There is now no apparent evidence to indicate that it should fail to isolate combinations many times more rare than any we have seen. If this breeding plan should prove to be so powerful, and we have no alternative to trying it out, it must be carefully directed. If we operate this breeding plan with thickly planted test plots of corn following the turning of a heavy crop of legumes with potash and phosphate to balance the nitrogen, the selection may be largely for drought resistance. This would be particularly likely on lighter soils. If the removal of heavier and more frequent crops of corn should cause a deficiency of, for example, magnesium which was sufficient in the older less intensive system, this deficiency might be hard to detect. For if the breeding system is powerful it will isolate the combinations which are more efficient and "normal" on the deficient soil. Progress will then deviate somewhat from the best course. I think it may be desirable for the soil chemist and plant physiologist to try to steer the plant breeder on the main course. For this reason I have been willing to try to outline the indefinite but promising state of our knowledge of the genetics of corn yield, and how we may use that knowledge in breeding corn for adaptation to soil and climate.

Of the genetics of yield in peanuts and oats we know even less than for corn. Each one of these crops is naturally closely inbred. There is little prospect of ever using hybrid seed commercially with either one. Oat breeding has so far been largely a matter of isolating disease resistance in pure strains.

Just how the principle of recurrent selection may be most efficiently employed in breeding such crops as peanuts and oats in relation to soil fertility and climate can only be determined by actual investigation of the problem with breeding experiments.

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SYMPOSIUM I: SOIL AND PLANT RESEARCH AS THE BASIS FOR A SOUND FERTILITY PROGRAM

Newell Hall, Friday, February 15, 1946
9:30 A. M.

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THE SIGNIFICANCE OF EXCHANGE REACTIONS IN THE SOIL

Dr. Nathan Gammon *

Normally, plants obtain many of their nutrients for growth from the exchange complex in the soil. This exchange complex which is the most important nutrient source in the soil consists of the finest soil particles, the soil colloids, which may be further subdivided into clay and organic matter. The clay particles are formed through the weathering of minerals over many centuries of time. The organic matter accumulates from the decomposition of the tissues of plants and animals which lived in or on the soil.

In order to follow the exchange reactions through a complete cycle, let us assume we start with a virgin soil which we wish to improve. The data in this paper are based on an analysis of a Leon fine sand but would not be very different from a number of Florida soils. For the sake of simplicity we will consider only the exchange reactions of the principal cations—potassium, calcium, and magnesium. However, in actual experience it would be necessary to consider anion exchange at the same time, since they greatly influence one another.

By chemical analysis we find that this soil contains only a small amount of active exchange-complex material. An average value for the exchange capacity should be about 5.0 M.E./100 gms. of dry soil, considering only the top 6 inches or normal plow depth. Further analysis reveals that only about one-tenth of this exchange complex is saturated with the nutrient bases, potassium, calcium, and magnesium. The balance of the material adsorbed on the exchange complex is hydrogen which only serves to increase the acidity of the soil. The pH of soil in this condition will average about 4.5. The total quantity of available cation nutrients per acre, considering the soil to plow depth, is roughly only 145 pounds of

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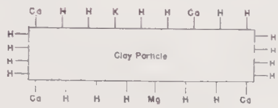
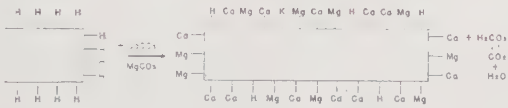
calcium, 55 pounds of potassium, and 8 pounds of magnesium. A clay particle in this virgin soil could be diagrammed approximately as follows:

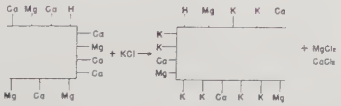


In order to reduce the acidity and increase the available calcium and magnesium on the exchange complex we apply a dolomitic limestone to the soil at the rate of 2 tons per acre. This will increase the available magnesium by about 400 pounds per acre and the available calcium by approximately 880 pounds per acre. The effect on the exchange complex will be somewhat as follows:



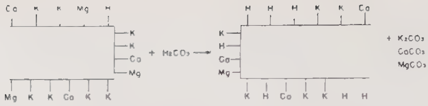
The carbonic acid is leached down into the subsoil and lost through the drainage water or decomposes, when the soil dries out, to carbon dioxide gas and water vapor and is then lost into the air. The pH of the soil has been raised, as a result of the exchange, from 4.5 to about 6.0. Approximately 10 percent of the exchange capacity is still saturated with hydrogen. This is a satisfactory condition since most plants grown in this area make a better growth on slightly acid soils.

By our treatment of the soil with lime we have greatly reduced the ratio of potassium to calcium and magnesium on the exchange complex. In order to increase the available potassium, we apply muriate of potash to our soil at the rate of 300 pounds per acre. This will increase the total available potassium in the soil by approximately 155 pounds per acre. The exchange complex responds to an application of muriate of potash in the following manner:



The calcium and magnesium chlorides formed by the above exchange reaction are leached down into the subsoil and are lost through the drainage water.

Now our exchange complex is considered to be in a high state of fertility as far as bases are concerned and is ready to supply these adsorbed bases to the plant root. It must be understood, however, that the exchange complex will not hold bases indefinitely against leaching and losses will occur at a relatively slow rate through the following reaction:



This reaction is very important since it continuously removes nutrient bases from the soil and could eventually replace all of the bases on the exchange complex with hydrogen. Such a condition would lead to the ultimate destruction of the exchange complex itself, since it tends to break down when fully saturated with hydrogen. Losses of this type are more rapid in light, sandy soils and are accentuated by heavy rains and high temperatures.

As our crop begins to grow and the roots extend out into the soil, one root-hair comes into contact with the exchange particle we have been representing. When this occurs, an exchange reaction takes place between the root-hair and the exchange particle. Hydrogen from the root-hair is exchanged for the nutrient bases on the exchange particle until a dynamic equilibrium is established. If the bases exchanged into the root-hair remained in the root-hair, only a limited exchange would take place; but since these bases are carried into the above ground portions of the plant after transfer from the exchange complex to the root, the exchange of bases into the root from the exchange particle will continue until most of the bases are removed. In this example the plant obtained the bases from the exchange particle by exchanging for hydrogen, since the root contained hydrogen and relatively few bases and the exchange particle was nearly saturated with bases. Had our exchange particle been saturated with hydrogen, it is possible for the reverse exchange reaction to take place so that bases are actually extracted from the plant root by the exchange particle. This would aid in more rapid mineral starvation of the plant instead of contributing to its nutrition.

We must realize that the growing plant has little ability to selectively absorb the nutrients available in the soil. Hence, if we saturate an exchange complex with calcium by excessive liming of the soil we may cause such an overwhelming number of calcium ions to be available as compared to other nutrients that the exchange equilibrium shifts to a point where deficiency symptoms of other elements such as potassium or magnesium appear. Likewise, an excessive application of potash could conceivably cause plants to become calcium or magnesium deficient. In other words, the plant root is not capable of selecting only the minerals it requires from the exchange complex but must take what is present in quantities dependent upon the equilibrium set up between the root and the exchange complex. The exchange complex is then a boarding-house rather than a cafeteria for the plant roots. From the foregoing remarks, it is easy to understand why studies of the exchange reaction in the soil are important in obtaining a balanced plant nutrition.

Another base exchange reaction which may be very important but which is not generally considered as part of the exchange complex is that which takes place when plant roots are in contact with raw, unweathered minerals. It is true that only a very small part of the total mineral content of a plant could be obtained in this manner but it is not the quantity

but the kind of minerals that may be obtained that has potential importance in this case. For example, it is known that plants can obtain sufficient iron for normal growth when the roots are in contact with the iron-bearing mineral, magnetite, and all other sources of iron are removed. Ordinarily, magnetite is not considered to have exchange properties and the iron it contains would be classified as unavailable for plant use. It is possible that further study of exchange reaction of this type may lead to better and cheaper methods of supplying trace elements to deficient soils by application of relatively insoluble minerals.

Many of the minerals removed by the plant root eventually are carried to the above ground portions of the plant. If the plant is permitted to grow and die in place, most of the bases will be returned eventually to the exchange complex with the remainder being lost in the drainage water through the continual leaching processes. When the plant is utilized through harvesting or grazing, an appreciable portion of the minerals are removed permanently from the exchange complex. All permanent losses of nutrients must be replaced through further additions of lime and fertilizer if the fertility level of the soil is to be maintained.

It is evident that the exchange reactions, even in soils containing relatively small quantities of the exchange complex, play a very important part in the soil. The exchange reactions aid in retaining valuable plant nutrients in soils and resist the soil-depleting effects of leaching. Nutrients adsorbed on the exchange complex are readily available to the roots of growing plants. Exchange complexes in many Florida soils have unused adsorption capacity for additional plant nutrients which, if properly utilized, should greatly increase the fertility level of these soils.

One of the most fundamental problems of all agricultural research is to keep the soil exchange complex and the exchange reactions at the level of optimum performance to facilitate plant nutrition and growth.

THE PLACE OF SOIL ANALYSIS IN DETERMINING A SOIL FERTILITY PROGRAM

DR. HENRY C. HARRIS *

It was with reluctance that I agreed to discuss the topic assigned me. I have been in the State only a short time and will not be able to give you anything new on the subject. For this reason all I can do is to give you my ideas, and as such, there is always room for differences of opinion.

There has been more work on the question of soil analysis in relation to the fertility program than perhaps any other phase of Soils Research. The January 1945 number of Soil Science had sixteen papers dealing with methods of soil analysis. They were not all on the fertility phase, but they will give you some idea of the quantity of work being done along this line, and how impossible it is for me to really cover the subject in the few minutes at my disposal. All I can do is to discuss a few points which interest me.

When I began to think about the title of this paper, I at once thought of a cartoon which I saw some years ago. An old man was plowing with a mule, and his son, who had just come back from college, went out to see him. Near them was a dog. The son said, "Dad, the thing to do is to have a soil analysis made". Whereupon the mule sat down on the singletree, the dog ducked his head, and the old man said, "Hah". The son had presented to his father the new idea that a soil analysis could be used to diagnose the situation on the individual farm, and the results used as a guide in determining the fertilizer that should be applied. My first reaction was that I was to talk on rapid chemical soil tests, but further reflection indicated that there was a second way the subject might be discussed, namely, the relation of soil analysis to the research program. I shall discuss briefly both phases of the subject.

First let me tell you what the prevalent idea was fifty or more years ago, and without discussing the details of the methods, some of the changes which have come about since then in our tests. You know Soil Scientists, like other people, do things in cycles. There was a time when most people were working on the nitrogen cycle, then at another period every one did pH determinations, at another time they all worked on base exchange, etc. The subject is not static. There are changes, and the motivating influence back of many of the changes has been an effort to arrive at the availability of soil nutrients to the plant.

We know that the growth of a plant depends upon a number of factors. Some of them may be listed such as: variety, amount and distribution of rain, temperature relations, disease, insect and other pests, drainage, physical relations of the soil, biological activity in the soil, chemical composition of the soil, and possibly many other factors. Since chemical composition is only one of many factors connected with the fertility problem, there was a feeling in the old days that chemical analysis of the soil gave practically no information as to the fertility problem. People were

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told that there was no known extracting solution that would remove from the soil the amount of nutrients that the plant would remove, and therefore a chemical analysis would give a poor index as to the availability to the plants of these elements. Considering the type of analysis made, I believe what was said was just about true.

In the early days the usual procedure was to make a total analysis, usually by the fusion method, for one element or group of elements in the soil. Such an analysis indicated the total supply of any element in the soil, but did not differentiate as to whether it was easy, difficult, or very difficult to get into solution. Of course, such an analysis did not help in telling how much the plant could get. It is possible, for example, for the total amount of phosphorus in a soil to be low, and yet the availability be good, and there be no response to phosphorus fertilization, and vice versa.

Do not understand me as saying that this type of analysis is worthless. In experimental work, where it is necessary to check on the total supply of any element, a total analysis is necessary, but it helps us very little in connection with the availability problem.

From time to time new methods of analysis have been devised in an effort to arrive at the amounts of elements in the soil more nearly available to plants. I might mention the 1/5 normal nitric acid and the one-per-cent citric acid method. Dyer,[1] in the case of the one-per-cent citric acid method, thought the acid concentration was about the same as that of the average root, and probably would extract from the soil about the same amount of elements as the crops. Field tests indicated that there was a relation between the responses to fertilizer, and the indicated need by the Dyer method, and yet the relation was by no means a perfect one.

In recent years all kinds of tests on soils have been made such as pH, exchangeable hydrogen, exchangeable bases, base exchange capacity, per cent of base saturation, phosphorus soluble in dilute acid, and the like. These determinations are made by standard quantitative methods, and will not be discussed here.

The point I wish to bring out is that exchange of ions are involved in most of these tests, and it is generally conceded that the exchangeable ions in the soil is the part most readily available to plants. For this reason there has sprung up around these tests for exchangeable elements numerous rapid soil tests. They frequently use some salt solution, such as sodium acetate buffered at pH 4.8, to replace the exchangeable ions and determine the respective ions by means of qualitative or semi-quantitative methods. Such a solution will extract some water soluble material, and some material soluble in a dilute acid, but most of it will be the exchangeable ions. The information secured from such a rapid test, while not as precise, is similar to that secured by the more rigorous quantitative methods.

Thus the soil chemists during the last 20 years have developed a number of rapid soil tests which are widely used in diagnosing the individual needs of the farmer. Some states test thousands of soil samples annually by these methods.

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[1] Dyer, Bernard. On the analytical determination of probably available "mineral" plant food in soils. Jour. Chem. Soc., 65:115-167. (1894).

The results of this type of test should not be swallowed, hook-line-and-sinker, so let me give you a few of the limitations of the rapid tests.

A test that works reasonably well on the coastal plain soils, for example, will not necessarily work in the Rocky Mountain area. The test has to be worked out and calibrated for the the conditions under which it is to be used. Even though the chemical tests are reproducible, the results are not always correlated with known field responses.

There are numerous difficulties in the way of getting a standardized technique which will give reproducible results in the same order as quantitative results. Many substances in a soil extract interfere in the determination of various ions such as arsenic with phosphorus, ammonium with potassium, calcium with magnesium, and the like. Furthermore, a nitrate test on a soil which has stood in a box in a moist condition is worthless. Peech and English,[2] have recently published a paper critically evaluating some of these points.

There are no rapid tests I know of that are at all satisfactory for certain ions, for example, the minor elements.

Then there is the difficulty of applying the results, especially to the intermediate cases. Before coming to Florida, I suppose I have tested 20,000 samples of soil by these rapid methods, and I never failed to spot places like gardens where there was high fertility. Many of the sandy soils, which were easily leached, tested very low. The difficulty was to draw the line between the two extremes as to where one would begin and end fertilization. Since many of the soils of Florida are sandy and highly leached, I suspect that many of them would test low, and only a few, those having special treatment or in unusual positions, would test high. Under these conditions there probably would not be too many transitional cases.

Furthermore, any supplemental information in regard to the nature of the crop or the soil management practice should be considered in connection with these rapid tests. The same soil type under poor management might need fertilizer, but under good management might not.

Let me summarize what I think about these rapid tests by saying that there are many difficulties, both in the determination and application of the results, and yet I believe tests of that nature secured by a careful worker are much safer guides than no information at all. Naturally all other information should be considered, but it seems to me that we are going in the direction of more of these tests. Fifty years ago I doubt that one could tell very much about fertility by a soil analysis, but my feeling is that during the intervening time we have made great progress, and I think that if all the tricks of the trade are applied, much now can be learned.

With reference to the question of soil analysis in connection with the research program let me give some examples of how it would help in a better understanding of the situation in connection with the soil fertility program.

I have just indicated that the results of rapid soil tests should be carefully correlated with plant response under field conditions. The best

[2] Peech, Michael and English, Leah. Rapid microchemical soil tests. Soil Science, 57:167-195. (1944).

place to calibrate such results is in connection with fertility experiments where general chemical information in regard to the soil is available.

Suppose one wished to find out whether lime is helpful to crops in this State and a number of tests are conducted. When the results are in, they probably will show that in some cases it was beneficial, in some cases it had no effect, and in some cases it was actually detrimental. Without such chemical information as the pH of the soil, exchange capacity, and the exchangeable calcium, the results cannot be properly interpreted. If the soil is already well filled with lime, additional lime would change the reaction of the soil to such an extent that the minor elements might be precipitated and the availability of other elements decreased, thus resulting in a detrimental effect. On the other hand, suppose the soil was low in lime, an application probably would be beneficial. The lime situation in sandy soils such as we have in this State is a delicate one. The base exchange capacity is very low in many cases, and it does not take much lime to saturate the soil. Furthermore, it is possible that in Florida we may have some of the lateritic types of soil colloids which are not very acid, even when there is little lime present. Under those conditions, it is possible to have a shortage of calcium in the soil even when the pH is not low. In such cases a small amount of lime applied more frequently might be valuable, but a large quantity at any one time might change the reaction to such a degree as to get one into trouble. In such lime experiments chemical information is necessary in order to properly evaluate the results.

Phosphorus fertilizers are important in this State both because they are manufactured here and are used liberally by the farmers. Now suppose one wished to find out whether phosphorus fertilization gave a response in some area of the State, and conducted an experiment to show that point. If moderate applications of phosphorus gave no response, would it prove that the soil did not need phosphorus? Not at all. There is such a thing as fixation of phosphorus by soils so that growing crops do not receive the added phosphorus. Furthermore, as a general thing, phosphorus is more available to plants when the pH value of the soil is near 6. No adequate explanation as to the response to phosphorus can be given until chemical information is available, especially in relation to fixation and the lime situation.

The nitrogen problem is definitely associated with the decomposition of organic matter. If the soil organic matter readily decomposes converting the nitrogen of the decomposing plant material into available nitrates, the growing crops are benefitted. On the other hand, if that transition does not occur, the growing crop may suffer from the lack of nitrogen. Lime is known to stimulate the nitrifying organisms. Furthermore, most legumes require lime in order to successfully grow, and fix nitrogen in the nodules on the roots of the plant. For these reasons lime has sometimes been called an indirect nitrogen fertilizer. Therefore any fertility problem dealing with nitrogen is not adequate without chemical information especially in connection with the lime situation.

Suppose a person were studying the minor elements and found that in one experiment a soil type responded to applications of boron. Would that mean that this soil type usually responds to boron? Not necessarily.

It could be that the area had been over limed. Overlimed soils frequently respond to boron, when otherwise they will not. A soil test would quickly indicate the overlimed condition.

I could take other essential elements and discuss them in a similar way, but the point is that in plant nutrition the effectiveness of any one element may be influenced by something else. We need soil analyses to round out the picture. Practically all science needs assistance from other fields. Some of the best soil chemists work pretty largely with physics, physicists become mathematicians, and mathematicians become astronomers. Soil tests supplement the information for the crops man. On the other hand, soil analysis should be supplemented by crop information. The final judge of what is available to the plant is the plant itself. In some of the best known methods of determining availability to the plant, the plant itself is analyzed to find out what it has been able to secure from the soil. In most cases one is primarily interested in a good crop. Many of the soil analyses are more inadequate without information as to what the plant took up than a fertilizer test without any soil analysis. The point is that we need well-rounded information.

Obviously we would be able to do fewer experiments if we undertook to get this more complete information, but I am wondering if that is not what we really should do. It seems to me that the fertility problem is a specific one, rather than a generalized one. Let me illustrate what I mean by that. The farmer wants to know what fertility program is good for his specific case and not what is good for the State in general. A fertilizer that is good for the State in general might in fact be very poor for many situations in the State. In order to understand best the fertility situation of any special area, it is necessary to have the supplementary chemical information about the soil. I am wondering, therefore, whether it would not be better to secure more, well-rounded information on selected situations, rather than have more experiments with less complete information. If that were done the individual results would apply to the local situations, and a few experiments of that type would fairly well cover the different situations in the State. In that way one would go from the specific programs to the more generalized program for the whole State. As I see it, in connection with the fertility problem, one never can take the generalized answer worked out for the average of the State, and apply it directly to the local situation. It is always an individual matter and must receive that type of consideration.

I am of the opinion, therefore, that more integrated research would be better. It seems to me that supplementary information is necessary in most problems and fertility studies are not complete without soil analysis.

A summary of what I have said is hardly necessary. I believe that there is a place for rapid soil tests and I am convinced there should be more chemical information concerning the soil where there are fertilizer experiments.

THE INFLUENCE OF SOIL TYPE ON THE RETENTION OF SOLUBLE PHOSPHORUS

Mr. G. T. Sims *

In 1943 several phases of research were initiated for the purpose of studying the nutritive value of foods produced in Florida and the factors influencing their quality. The Horticulture Department laid out some plot tests throughout the State on several different soil types. Some results obtained from the crops used have already been reported by Dr. B. E. Janes in his paper entitled, "The Relative Effect of Variety and Environment in Determining the Variations of Per Cent Dry Weight, Ascorbic Acid and Carotene Content of Cabbage and Beans[1]." Through cooperation with the Horticulture Department soil samples were collected from these experimental plots and analyzed by the Soils Department. Results of these analyses together with treatments applied and crop yields obtained are reported in this paper.

PLAN OF EXPERIMENT

The kind and amounts of fertilizer used in each area were based on what was considered to be a normal practice in the area. Three treatments were used in each area. The normal rate comprised one treatment. The other two rates were $\frac{1}{2}$ and $1\frac{1}{2}$ times normal, except at Sanford where the highest rate was only $1\frac{1}{4}$ times the normal. Two vegetable varieties were used in every experiment.

Fourteen experiments from which soil samples were taken consisted of 12 plots each. One at West Palm Beach consisted of 21 plots. Replications for each fertilizer rate and each vegetable variety occurred 4 and 6 times respectively in all 12-plot experiments, and 8 and 12 times in the bean experiment at West Palm Beach.

The soils used for all experiments had been allowed to remain fallow for at least six months prior to planting these tests. This was considered sufficient time for natural soil conditions to overcome any major variations in fertilizer applications previously applied. Therefore, it is assumed that data obtained in the analysis of soil samples taken from each experiment just before planting or fertilization would represent the normal state of the soils at the time of their respective planting seasons. The planting seasons ran from October through March.

EXPERIMENTAL METHODS

Surface soil samples consisting of a composite of 15 to 18 plugs were collected from every plot before planting and at time of crop harvest, except at Belle Glade and West Palm Beach. Only duplicate preplant samples were taken from the whole experiment on which cabbage and

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[1] Published in the Proceedings of the American Society for Horticultural Science, Vol. 45, 1944.

beans were planted at Belle Glade and from the cabbage experiment at West Palm Beach. All soil samples were air-dried, sieved through a 2 m.m. sieve, and stored in moisture-proof containers for analysis. Moisture equivalent values were determined by the centrifuge method and calculated to an oven dry basis. Organic matter content was determined on soils, low in organic matter, by the modified Schollenberger method and by loss on ignition on the mucks and peats. Soil pH was determined potentiometrically with the glass electrode using 50 gms. soil to 100 mls. distilled water. Soluble phosphorus was determined colorimetrically after extraction with 0.002 N sulfuric acid buffered to pH 3.0 with ammonium sulfate.

RESULTS

These experiments were designed primarily for horticultural tests. The variations in fertilizer formulas and rates applied to the different experiments precluded a study of many important soil type relationships that might have been found if these factors had been constant. However, the soil data together with yields obtained show some interesting and unexplainable differences.

The graph in Fig. 1 shows the average pounds per acre of 0.002 N sulfuric acid soluble phosphorus found in the soils on which each experiment was located. It also shows the average phosphorus applied in each of the three treatments and the soluble phosphorus found in the harvest soil samples. Hereafter the 0.002 N sulfuric acid soluble phosphorus shall be referred to as soluble or readily available phosphorus.

The levels of soluble phosphorus found in the preplant soil samples varied tremendously. The Manatee fine sandy loam at Bradenton on which cabbage was grown contained an average of 1203 lbs. per acre while only 3 lbs. per acre were found in the preplant soil samples taken from the experiments on Marl soil at Homestead on which tomatoes were planted. Everglades peat at Belle Glade was next lowest with 28 lbs. per acre. The Arredondo fine sandy loam at Gainesville was second highest, containing 515 lbs. per acre at time of planting.

Despite the high level of soluble phosphorus present in the Manatee fine sandy loam at time of planting, the average fertilizer treatment used there contained more phosphorus than was applied to any other experiment. These plots gave an average yield of 12.1 tons of cabbage per acre which was the second highest yield obtained from all experiments. The soluble phosphorus retained in the soil at time of harvest at Bradenton was greater than that of the preplant level plus that applied in the fertilizer. Taking the plots by treatment, it can be seen in Table 1, that only the 4 plots to which the lowest fertilizer treatments were applied and which gave the lowest average yields were those in which the soil showed an increase in soluble phosphorus recovery. Yield increases were obtained from plots that received the normal and 1½ normal treatments.

Figures given in Table 1 are the averages obtained from plots to which the same treatments were applied. These data in the Table are arranged according to treatment. The phosphorus applied in the fertilizer used for each treatment is shown in the third column.

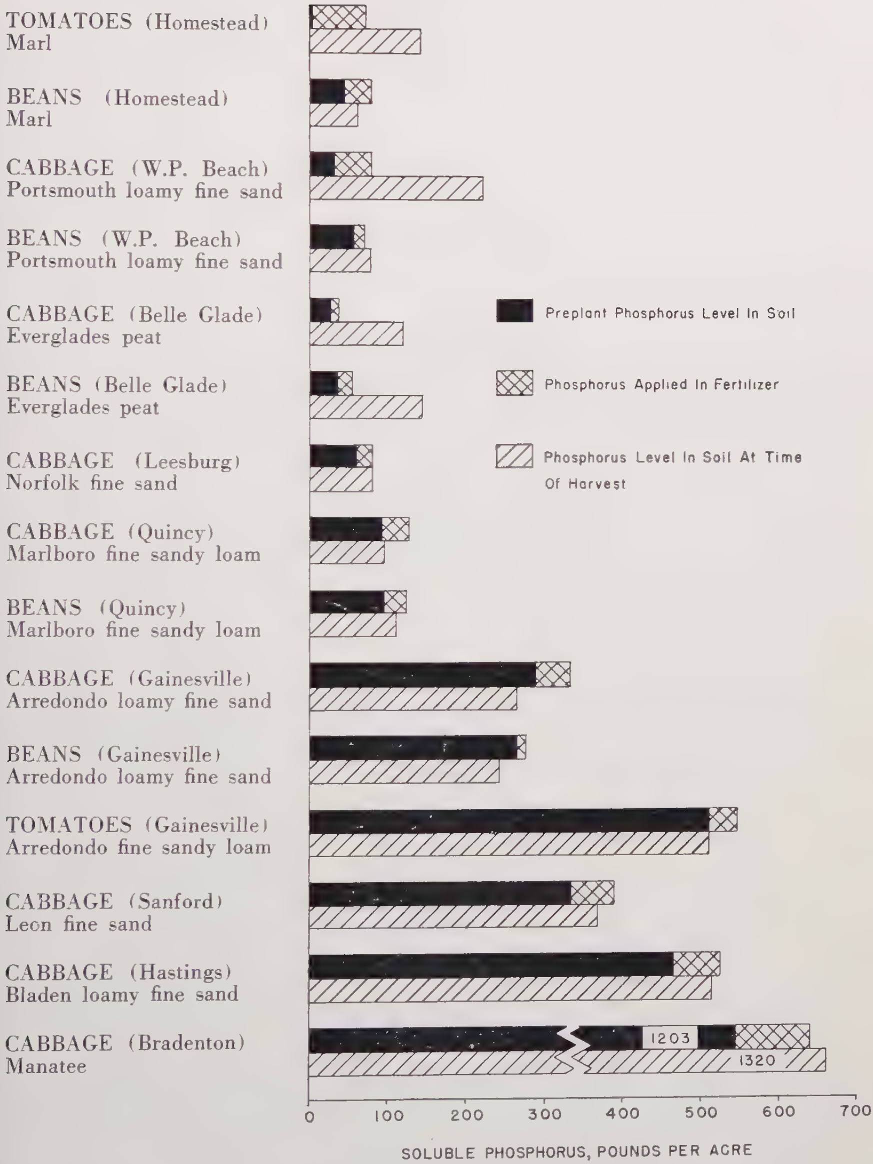

Figure 1.—The retention of soluble phosphorus in soils of different types when subjected to treatment and cropping.

Preplant soil samples from plots on Bladen loamy fine sand at Hastings contained about 1/3 as much soluble phosphorus at time of planting and received only 2/3 as much fertilizer, containing the same per cent phosphorus but yielded an average of 0.7 of a ton more cabbage than

TABLE 1.—Retention and Maintenance of Soluble Phosphorus in Different Soil Types Under Various Cropping Systems.

Location, Soil Type, Crop Used and Date of Planting	Treatments Used		Soil Analyses								Crop Yields ***	P Recovery (P applied plus pre-plant P minus harvest P)
	Fertilizer Formula	P Applied in Fert.	Lbs./A Sol. P Found		% Organic Matter		% Moisture Equivalent		pH			
			Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest		
Bradenton	4-5-7	48	1160	1320	1.73	1.81	6.62	7.08	7.47	7.15	10.2	+ 112*
Manatee f.s.l.	4-5-7	96	1215	1300	1.60	1.80	6.36	6.77	7.24	6.92	12.6	— 11
Cabbage 11-19-43	4-5-7	144	1235	1340	1.62	1.80	7.08	6 96	7.28	6.90	13.5	— 39
Average		96	1203	1320	1.65	1.80	6.68	6.94	7.33	6.99	12.1	+ 21
Hastings (irrigated)	5-7-5	31	457	520	2.54	2.31	8.92	8.89	4.85	4.70	10.8	+ 32
Bladen l.f.s.	5-7-5	61	481	503	2.30	2.84	8.40	9.36	4.91	4.57	13.5	— 39
Cabbage 10-28-43	5-7-5	92	460	518	2.58	2.39	8.67	9.08	4.86	4.58	13.3	— 34
Average		61	466	514	2.47	2.69	8.67	9.11	4.87	4.62	12.8	— 13
Gainesville (irrig.)	6-8-6	22	299	269	1.38	1.33	4.83	4.96	5.77	5.59	2.8	— 52
Arredondo l.f.s.	6-8-6	45	277	267	1.24	1.29	4.45	4.71	5.88	5.71	4.6	— 55
Cabbage 11-2-43	6-8-6	67	286	259	1.28	1.31	4.72	4.87	5.85	5.65	3.3	— 94
Average		45	287	265	1.30	1.31	4.67	4.85	5.83	5.65	3.6	— 67
Gainesville (irrig.)	4-7-5	6	269	239	1.33	1.38	4.96	4.92	5.59	5.35	107	— 36
Arredondo l.f.s.	4-7-5	12	267	245	1.29	1.30	4.71	4.82	5.71	5.56	156	— 34
Beans ** 3-1-44	4-7-5	18	259	241	1.31	1.34	4.87	4.84	5.65	5.57	158	— 36
Average		12	265	242	1.31	1.34	4.84	4.86	5.65	5.49	140	— 35
Gainesville	4-7-5	18	532	515	2.18	1.77	12.00	11.20	5.74	5.48	31	— 35
Arredondo f.s.l.	4-7-5	36	525	525	2.12	1.74	12.10	10.72	5.56	5.41	41	— 36
Tomatoes 3-14-44	4-7-5	55	480	495	2.23	1.63	11.01	10.03	5.60	5.34	37	— 40
Average		36	512	512	2.18	1.71	11.70	10.65	5.63	5.41	36	— 37

TABLE 1.—*Cont.*

Location, Soil Type, Crop Used and Date of Planting	Treatments Used		Soil Analyses								Crop Yields ***	P Recovery (P applied plus pre-plant P minus harvest P)
	Fertilizer Formula	P Applied in Fert.	Lbs./A Sol. P Found		% Organic Matter		% Moisture Equivalent		pH			
			Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest		
Quincy	4-8-7	18	98	100	2.65	2.53	10.89	9.30	5.00	5.06	7.2	— 16
Marlboro f.s.l.	4-8-7	35	91	95	2.71	2.66	11.14	9.62	4.96	5.10	7.2	— 31
Cabbage 12-8-43	4-8-7	52	91	100	2.66	2.59	10.83	9.28	4.98	5.13	7.6	— 43
Average		35	93	97	2.67	2.59	10.95	9.40	4.98	5.10	7.3	30
Quincy	3-8-5	14	100	100	2.53	2.27	9.30	9.18	5.06	4.76	102	— 14
Marlboro f.s.l.	3-8-5	28	95	111	2.66	2.46	9.62	8.21	5.10	4.78	117	— 12
Beans ** 3-23-44	3-8-5	42	100	125	2.59	2.16	9.28	9.01	5.13	4.70	109	— 17
Average		28	97	112	2.59	2.30	9.40	8.80	5.10	4.74	109	— 14
Homestead	4-8-6	17	44	54	5.77	5.88	61.62	59.89	7.71	7.56	305	— 7
Marl (East Glades)	4-8-6	35	51	70	5.88	5.78	61.91	59.93	7.72	7.56	376	— 16
Beans 3-7-44	4-8-6	52	41	65	5.74	5.71	62.07	60.00	7.67	7.56	354	— 28
Average		35	45	63	5.80	5.79	61.87	59.94	7.70	7.56	360	17
Homestead	3-8-6	35	3	84	9.15	8.62	69.91	66.52	7.58	7.50	94	+ 46
Marl (Highlands)	3-8-6	70	3	144	7.97	8.03	68.12	65.12	7.61	7.46	115	+ 71
Tomatoes 2-3-44	3-8-6	105	2	198	9.21	9.55	69.84	65.93	7.58	7.29	115	+ 91
Average		70	3	142	8.78	8.73	69.29	65.80	7.59	7.42	108	+ 69
Leesburg	4-7-5	11	55	65	0.96	1.14	3.34	3.17	5.67	5.58	2.5	— 7
Norfolk f.s.	4-7-5	21	66	80	1.07	1.19	3.25	3.25	5.74	5.73	3.1	+ 6
Cabbage 10-29-43	4-7-5	32	59	97	0.98	1.05	2.97	2.77	5.75	5.62	5.3	— 1
Average		21	60	81	1.00	1.13	3.19	3.06	5.72	5.64	3.6	— 1

TABLE 1.—*Cont.*

Location, Soil Type, Crop Used and Date of Planting	Treatments Used		Soil Analyses								Crop Yields ***	P Recovery (P applied plus pre-plant P minus harvest P)
	Fertilizer Formula	P Applied in Fert.	Lbs./A Sol. P Found		% Organic Matter		% Moisture Equivalent		pH			
			Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest	Pre-plant	Harvest		
Sanford	4-7-5	31	305	370	1.47	1.78	3.96	4.01	5.22	5.22	2.5	+ 34
Leon f.s.	4-7-5	61	338	343	1.50	1.76	4.37	3.57	5.36	5.06	4.2	− 56
Cabbage 10-29-43	4-7-5	77	358	393	1.74	1.80	4.89	3.79	5.27	4.89	6.1	− 42
Average		56	334	369	1.57	1.78	4.41	3.79	5.28	5.06	4.3	21
West Palm Beach	4-7-5	8	57	72	11.1	10.90	17.62	16.80	5.49	5.28		+ 7
Portsmouth l.f.s.	4-7-5	15	57	78	11.6	11.20	16.56	16.99	5.55	5.30		+ 6
Beans 1-18-44	4-7-5	23	55	86	11.6	10.70	16.55	16.32	5.53	5.31		+ 8
Average		15	56	79	11.4	10.93	16.91	16.70	5.52	5.30		+ 7
West Palm Beach	4-5-7	24	32	157	4.83	5.24	7.94	8.18	5.83	5.62		+ 101
Portsmouth l.f.s.	4-5-7	48	32	195	4.83	4.83	7.94	7.13	5.83	5.51		+ 115
Cabbage 11-4-43	4-5-7	72	32	314	4.83	4.59	7.94	7.93	5.83	5.38		+ 210
Average		48	32	222	4.83	4.89	7.94	7.75	5.83	5.50		+ 142
Belle Glade	0-8-24	5	28	111	86.4	86.45	103.72	108.95	5.74	5.54	6.2	+ 78
Everglades Peat	0-8-24	10	28	115	86.4	86.95	103.72	107.70	5.74	5.54	6.3	+ 77
Cabbage 11-27-43	0-8-24	15	28	134	86.4	85.85	103.72	108.53	5.74	5.56	7.0	+ 91
Average		10	28	120	86.4	86.41	103.72	108.39	5.74	5.55	6.5	+ 82
Belle Glade	0-14-6	9	38	134	86.20	85.2	105.48	111.77	5.42	5.09	145	+ 87
Everglades Peat	0-14-6	18	38	147	86.20	85.5	105.48	109.12	5.42	5.06	163	+ 91
Beans 2-25-44	0-14-6	27	38	150	86.20	85.4	105.48	109.28	5.42	5.13	154	+ 85
Average		18	38	144	86.20	85.4	105.48	110.05	5.42	5.09	154	+ 87

* Each line represents the average of four plots that received the same treatment.
** Planted on the same plots as the preceding cabbage tests.
*** Cabbage yields are given in tons per acre; beans in bushels per acre and tomatoes in pounds per plot.

did the plots on Manatee fine sandy loam at Bradenton. Yields, from both locations, correlated with treatment but phosphorus recovery in the soils decreased under the normal and 1½ normal treatments. The pH of the Bladen soil was about 2.5 units lower than the nearly neutral Manatee soil. Both soils decreased proportionately in pH during the growing season.

The data obtained from cabbage, bean and tomato experiments on Arredondo soil at Gainesville: from cabbage and beans on Marlboro at Quincy and from the bean experiment on Marl at Homestead all gave decreases in phosphorus recovery for all treatments. Furthermore the highest treatments applied gave decreases in phosphorus recovery and yields from the cabbage and tomato plots at Gainesville; and from the bean plots at Quincy and Homestead. Yields resulting from the highest treatment applied to the bean plots at Gainesville gave only about a one per cent increase over the normal or medium treatment. And in these plots there was hardly any difference in the phosphorus recovery regardless of yield or treatment.

Bean experiments on Arredondo soil at Gainesville and on Marlboro at Quincy were planted on the same plots as the preceding cabbage experiments. All the bean plots at both locations were treated with the same corresponding treatments as was previously applied to the cabbage plots, but the actual quantities of fertilizer used were less.

Uniform changes in the phosphorus levels occurred in the Arredondo loamy fine sand at Gainesville during the production of two crops. The harvest soil samples taken at time of cabbage harvest contained an average of 22 pounds per acre less soluble phosphorus than was found in the preplant samples. A further decrease of 23 pounds per acre in the harvest samples occurred during the succeeding bean growing period.

The tomato experiment on Arredondo fine sandy loam at Gainesville was located about one hundred yards up a gentle slope from the cabbage and bean plots. In these plots no change was found in the average phosphorus level between the preplant and harvest soil samples.

Data obtained from the bean and tomato experiments on Marl at Homestead show some interesting variations. The soil of the East Glades experiment on which beans were planted contained an average of 45 pounds soluble phosphorus per acre at time of planting and increased to only 63 lbs. per acre at time of harvest. An average of 35 pounds per acre was applied in the fertilizer and the resultant decrease in phosphorus recovery was 17 pounds per acre. The tomato plots showed entirely different results. The phosphorus found in the preplant soil samples from the tomato plots at Homestead was only 3 pounds per acre and rose to 142 pounds per acre at time of harvest. The average phosphorus application was about 70 lbs. per acre and the resulting phosphorus recovery was 69 lbs. per acre. In each case the optimum treatment for crop production seemed to be the normal fertilizer rate applied.

Norfolk and Leon fine sands at Leesburg and Sanford differed rather peculiarly in their ability to retain soluble phosphorus. The preplant soil sample from the Leon fine sand contained more than 5 times as much as the Norfolk at Leesburg. The lowest treatment applied to the Leon soil gave the lowest average yield and the greatest phosphorus recovery.

Only one pound more of phosphorus was contained in the highest treatment applied to the Norfolk soil at Leesburg which gave the greatest phosphorus recovery and the highest yield.

Phosphorus recovery in the West Palm Beach and Belle Glade experiments was rather closely associated with treatments. Yield records were not obtained at West Palm Beach, but yields and phosphorus recovery seemed to be closely associated in both the cabbage and bean experiments on Everglades peat at Belle Glade.

DISCUSSION OF RESULTS

The physical and chemical soil characteristics as determined here, varied widely between soil types. None of these characteristics alone however, could specifically account for the variations in the levels of soluble phosphorus found in the soils at time of planting. The highest soluble phosphorus levels in the preplant soil samples were found more often in soils which were rather low in organic matter but had comparatively high moisture equivalents. And in general those soils high in organic matter contained less soluble phosphorus at the time of planting.

Soil pH ranged from 4.4 to 7.5; organic matter from about 1 to 86.4 per cent and moisture equivalent from 3.2 to 109.5 per cent.

Differences in one or more soil characteristics within the same type was generally associated with the variations in the preplant soluble phosphorus levels found between plots in the same experiment. Figure 2 shows the influence of moisture equivalent and organic matter on the retention of soluble phosphorus in Bladen loamy fine sand at Hastings on which the cabbage experiment was planted. These data are somewhat representative of most experiments. Moisture equivalent alone seemed to be the most important factor associated with phosphorus retention in the Arredondo fine sandy loam at Gainesville on which tomatoes were grown.

Soil analyses for the Bradenton and Hastings experiments showed high levels of soluble phosphorus. Both experiments gave similar results in regard to yields and phosphorus recovery, yet their soil characteristics were quite different. If the crop demands for phosphorus in the plots which received the highest treatments and which gave the highest yields was as great as indicated by the decreased phosphorus recovery, it would seem that the phosphorus level in the harvest samples would also have decreased. In view of the fact that only about 4 pounds of phosphorus is contained in 10 tons of cabbage, most of the phosphorus applied was removed by some other means than through the crop.

From the data obtained in this study there seems to be two groups of soils which can be discussed together because of the somewhat similar results obtained regarding their retention and maintenance of soluble phosphorus.

One group of soils used gave decreases in phosphorus recovery under all treatments regardless of yields. The experiments included in this group are those on Arredondo loamy fine sand and fine sandy loam at Gainesville; on Marlboro fine sandy loam at Quincy and the bean experiment on Marl at the East Glades farm in Homestead.

The second group that can be discussed together are those which gave increased phosphorus recoveries under all treatments. All soils in this

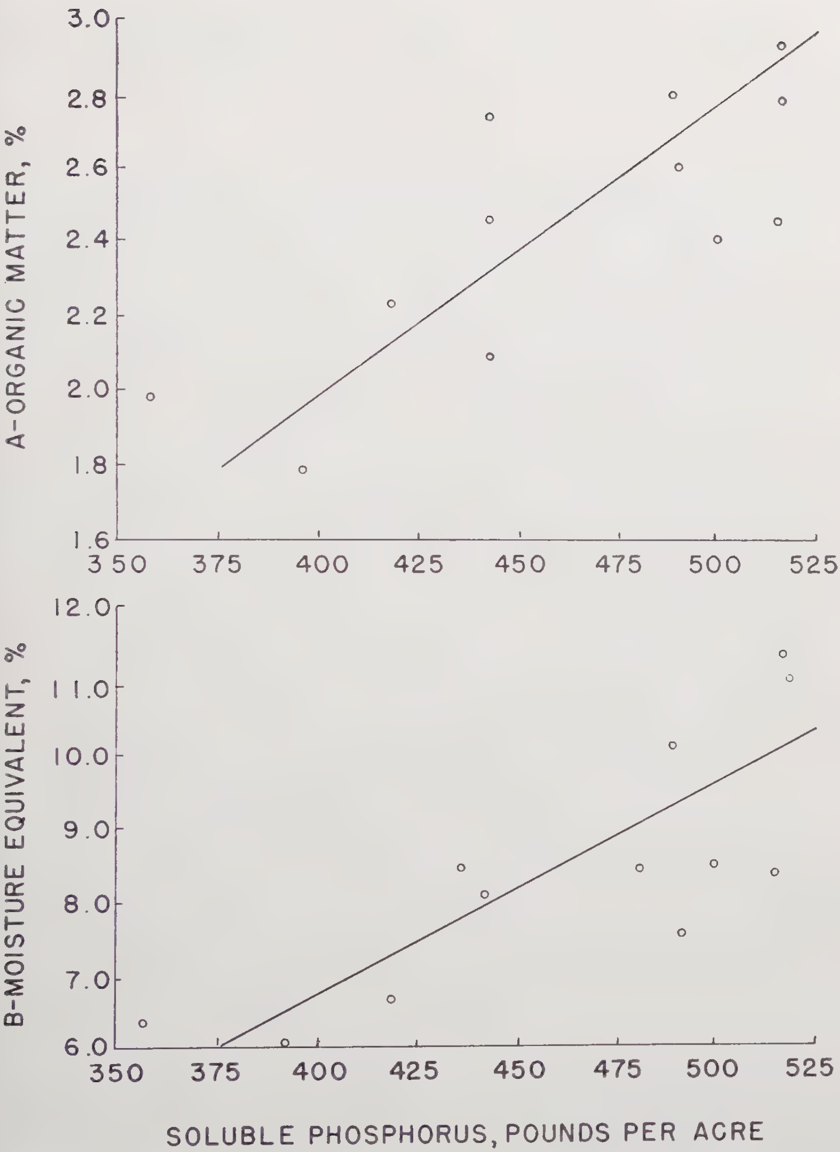

Figure 2.—Correlation of organic matter content and moisture equivalent value with retention of soluble phosphorus in a Bladen loamy fine sand at Hastings.

group were also characterized as containing 4 per cent or more organic matter. Included in this group are the bean and cabbage experiments on Everglades peat at Belle Glade and Portsmouth loamy fine sand at West Palm Beach and the tomato experiment on Marl at Homestead.

In general the soils highest in organic matter contained less soluble phosphorus at the time of planting but gave greater increases in phosphorus recovery than the more mineralized soils containing less organic matter.

CONCLUSIONS

Numerous explanations may be offered as to the differences in the data obtained from these experiments on several soil types. But from the data shown here the most practical explanation must lie in the changes that take place in the soil solution of various soil types when certain essential and non-essential constituents are applied in fairly large quantities to the soils.

Phosphate ions in the soil solution are known to assume different valences and to form numerous complexes, the nature of which is influenced largely by the nature of the exchange complex, its ions and the ions added in the fertilizer mixtures.

In some of the more mineralized soils having a fairly high colloidal content certain elements might have been present in sufficient quantities to satisfy plant requirements even after fixation had taken place. Such conditions might have caused the decreases in phosphorus recovery without affecting yields in the cabbage experiments at Sanford, Belle Glade, Bradenton and Quincy.

Under certain other soil conditions one or more essential elements, present in minute quantities, might be included in this fixation. In this case a deficiency would occur which would limit or depress yields in proportion to the fixation that took place. A deficiency of this kind might account for the low yields associated with low phosphorus recoveries in the cabbage and tomato experiments at Gainesville and the bean experiments at Quincy and Homestead.

Most of the essential minor elements are known to be deficient in all the Glades peats and Marl soils. Manganese, zinc and copper were added to the soil used for the cabbage experiment on Everglades peat but not to the bean experiment, which could account for the lack of correlation between treatment and yields from the bean plots on Everglades peat. Manganese was applied to both experiments on Marl at Homestead. Had the soils used for the bean experiments at Homestead contained the same amount of organic matter and received the same treatments, similar results might have been obtained from both experiments in regard to phosphorus retention.

These data obtained from experiments located throughout the State show that plant-soil relationships are widely different with each soil type and that considerable variations may be expected even from the same soil type in different areas.

LEACHING AND THE AVAILABILITY OF COPPER AS AFFECTED BY PHOSPHORUS AND LIME

MR. T. C. ERWIN *

There has been some evidence [1] that with increasing soil applications of phosphorus there is less assimilation of copper from the soil by some plants. It has also been shown[2] that applications of superphosphate to some soils will increase the leaching of this element. In view of these reported facts an experiment was designed to study simultaneously the effect of varying amounts of phosphorus and lime in relation to copper leaching on the one hand and its availability to plants on the other.

EXPERIMENTAL PLAN

Thirteen treatments with varying amounts of phosphorus, lime and copper were set up in 4-gallon lysimeter pots having hard, glazed surfaces inside and out. The surface 8 inches of a virgin, Norfolk fine sand was used. The pots were set in the ground with appropriate outlets from below and exposed to natural weather conditions. The phosphorus was supplied from C.P. mono-calcium phosphate, the copper from C.P. copper

TABLE 1.—INITIAL TREATMENTS GIVEN A NORFOLK FINE SAND UNDER LYSIMETER CONDITIONS AND THE RESULTING pH OF THE SOIL UNDER EACH CONDITION. *

Soil Treatment No.	Calcium Hydroxide $Ca(OH)_2$ (Tons per Acre)	Mono-Calcium Phosphate $Ca(H_2PO_4)_2.H_2O$ Equivalent to: (Lbs. P_2O_5 per Acre)	Copper Sulfate $CuSO_4.5H_2O$ (Lbs. per Acre)	pH of Soil	
				Time of Seeding	Second Plant Sampling
1	0.8	——	50	6.9	6.9
2	0.8	140	50	6.8	6.8
3	0.8	350	50	6.9	6.8
4	0.8	700	50	6.7	6.7
5	0.8	1400	50	6.8	6.8
6	0.8	2000	50	6.7	6.7
7	0.8	1400	—	6.8	6.8
8	0.8	1400	500	6.7	6.8
9	—	140	50	5.7	5.8
10	1.6	140	50	7.7	7.7
11	—	1400	50	5.7	5.9
12	1.6	1400	50	7.5	7.5
13	3.2	1400	50	7.7	8.0

* Treatments made October 26, 1944.

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[1] Forsee, W. T., Jr. and R. V. Allison. Evidence of Phosphorus Interference in the Assimilation of Copper by Citrus on Organic Soils of the Lower East Coast of Florida. Proc. Soil Sci. Soc. of Fla. Vol. VI. 1944.

[2] Jamison, V. C. The Behavior of Manganese, Copper and Zinc in the Organic Exchange Complexes of some Florida Soils. Proc. Soil Sci. Soc. of Fla. Vol. VI. 1944.

sulfate with $5H_2O$ (bluestone), and the lime from a "purified" grade of calcium hydroxide. These compounds were applied by mixing them thoroughly with the air-dry soil before placing it in the pots.

The thirteen treatments were set up in quintuplicate according to Table 1 except for treatment No. 6 of which there were only four replicates. This made a total of 64 treated lysimeters, each representing 1/50,000 of an acre in area.

The pots were filled October 26 and wet with equal quantities of tap water. The amount of water used was not enough to cause leaching. Leaching did not begin until the second month, when the rainfall increased slightly. The pots were exposed to normal weather conditions for five months in order to reach a reasonable degree of equilibrium. During this time several samples of leachate were collected and analyzed spectrographically by a rough estimate method. The analyses indicated the amount of copper lost due to leaching to be less than 0.5 percent of the copper added. This, of course, is an insignificant amount. Each pot was then treated with a solution of C.P. potassium nitrate equivalent to 110 pounds per acre and then seeded with pearl millet.

The millet came up to a good stand in all pots and it was then thinned to one plant per pot. One month later the plants in all the pots began to show a yellowing which suggested some overall deficiency. Each culture was then treated with the equivalent of 5.5 pounds of boric acid (H_3BO_3), 11 pounds of zinc sulfate ($ZnSO_4.7H_2O$), 55 pounds of magnesium sulfate ($MgSO_4.7H_2O$) and 55 pounds of manganese sulfate ($MnSO_4.4H_2O$) per acre.

Two weeks later the first samples of millet leaves and stems were taken. Leachate samples were taken at the same time. The latter samples represented the total leachate from shortly before the millet was planted. The millet samples from the same treatments were combined thus making thirteen samples in all.

The millet grew out from the stubble left in the pots. This time no evidence of yellowing appeared. Neither was there observed at any time any significant difference in growth of the millet on any of the treatments. Two months after the first sampling, the plants were sampled for the second time. Another leachate sampling likewise was taken. The millet leaves and stems were all retained as separate samples making a total of 64. The seed heads from the same treatments were combined giving thirteen additional samples. All leachates were maintained as separate samples, making a total of 128.

The last two series of leachate samples and the millet samples were analyzed for copper spectrographically by the use of a quantitative internal standard. The leachates of the last series were also analyzed for phosphorus.

PRESENTATION OF DATA

Figures 1 and 2 show the copper content of millet and the leachates from the two samplings for the six treatments where the amount of monocalcium phosphate used in the initial soil treatment was the only variable. The points on Curve I and II of Figure 1 are the results of analyses made on the combined samples from the same treatments. All the other points are based on averages of analyses of 4 or 5 samples receiving the same

treatments. These curves represent treatments 1 through 6, all of which had 50 pounds of copper sulfate and 0.8 tons calcium hydroxide per acre besides the varying amounts of mono-calcium phosphate. (See Table 1).

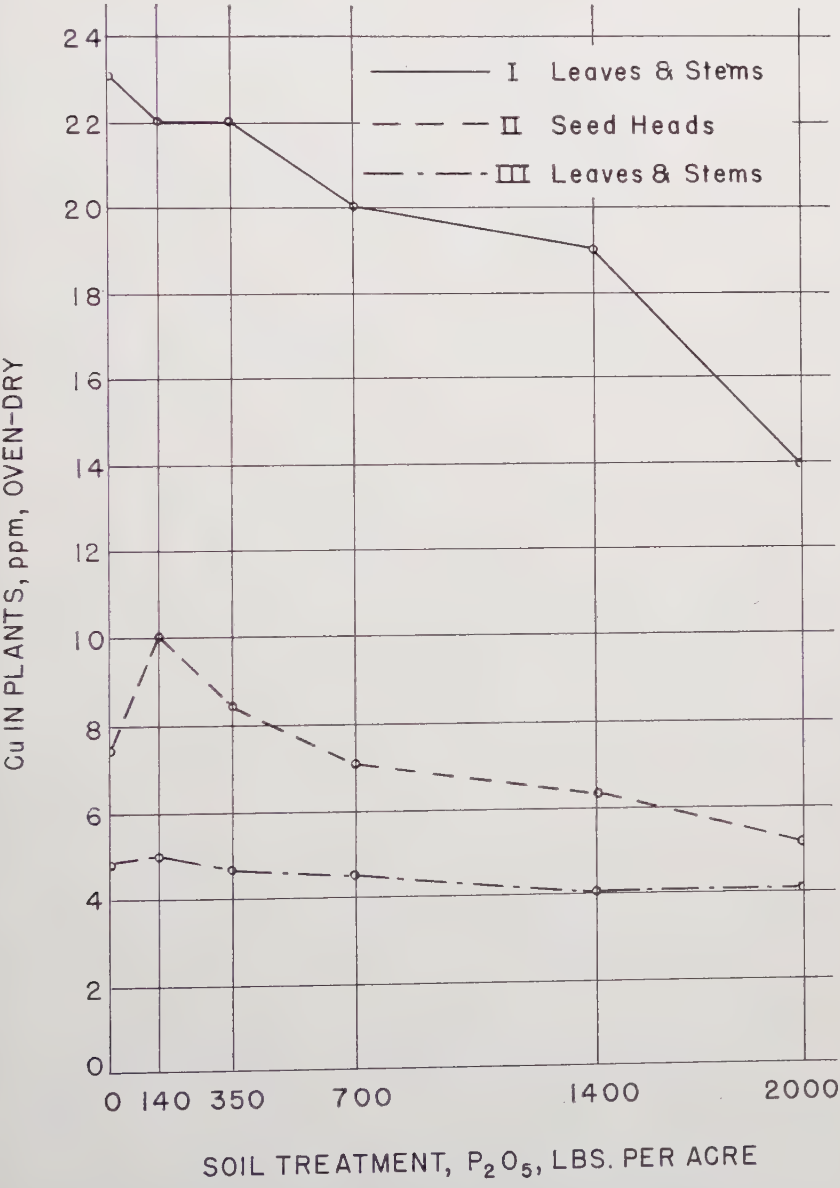

Figure 1.—Effect of variable phosphorus treatment upon the copper content of millet plants growing in a Norfolk fine sand under lysimeter conditions in the open. (Curve I first sampling. Curves II and III second sampling.)

The above treatment gave a soil pH of about 6.7 for all pots. An examination of Figure 1 shows that the amount of copper in the plant decreases with increasing amounts of phosphorus in the soil treatment, while, at the same time, the copper in the leachate increases up to a certain rather high level of phosphorus treatment and then decreases at the higher levels of this element. The large difference between the copper in the first and second samplings of millet is probably due, in part at least, to the lower availability of copper at the time of the second sampling; partly perhaps also to the state of maturity of the millet at the time of the latter sampling. However, as will be shown later, the effect of time on the influence of lime may be the major factor. In studying Figure 2 it should be kept in mind that Curve I represents leaching which took place five months after soil treatments and Curve II that which took place about seven months after soil treatments.

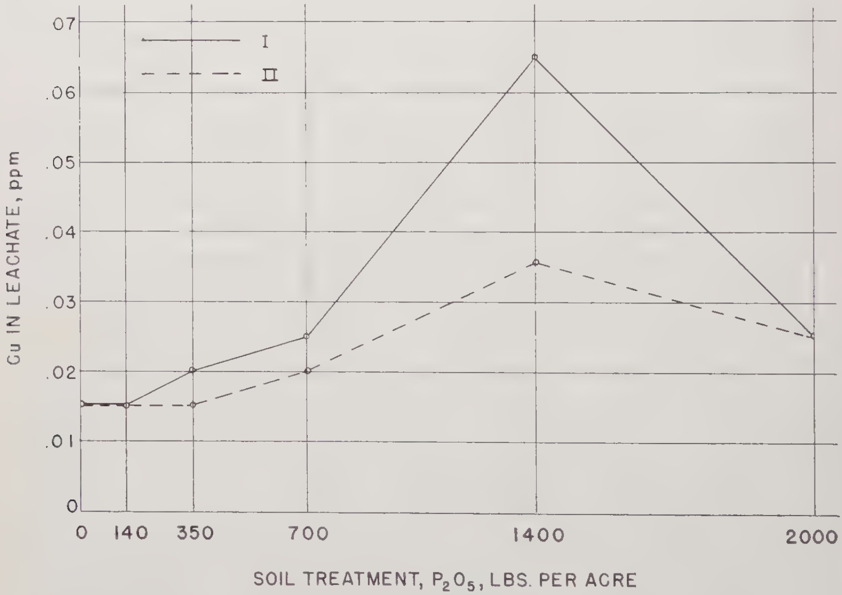

Figure 2.—Effect of phosphate treatment upon the copper content of leachates received from millet cultures growing in Norfolk fine sand as referred to in Fig. 1. (Curve I first sampling. Curve II second sampling.)

The influence of mono-calcium phosphate on copper seems to be true at various levels of pH in the soil. Table 2 gives the results for two levels of phosphorus at two different soil pH levels. It will be noted that the same trends are evident in the first millet sampling and in both leachate samplings. However, these trends are not so evident in the second millet sampling. The higher pH seems to increase the copper in the plant and decrease it in the leachate at the time of the first sampling. This is apparent from Figures 3 and 4 where calcium hydroxide is the only variable in the soil treatment. It will be noted, however, that the plant response seems to level off by the time of the second sampling, as was indicated

TABLE 2.—VARIATION OF COPPER IN MILLET AND IN LEACHATE WITH DIFFERENT PHOSPHORUS TREATMENTS AT TWO LEVELS OF SOIL pH. ALL TREATMENTS INCLUDE 50 POUNDS COPPER PER ACRE.

pH	P_2O_5 per Acre (Lbs.)	Copper in Leachate (p.p.m.)		Copper in Millett (p.p.m.) *		
				First Sampling	Second Sampling	
		First Sampling	Second Sampling	Leaves and Stems	Leaves and Stems	Seed Heads
5.8	140	.055	.004	23	4.2	7.4
	1400	.090	.050	9	4.4	5.5
7.5	140	.025	.025	50	4.2	5.6
	1400	.040	.027	17	4.1	6.2

* Oven Dry Basis.

in Table 2. An examination of Figures 5 and 6 would indicate that the same response to calcium hydroxide is obtained when a lower level of phosphorus is used except for a rather different result in the leachate at the time of the second sampling.

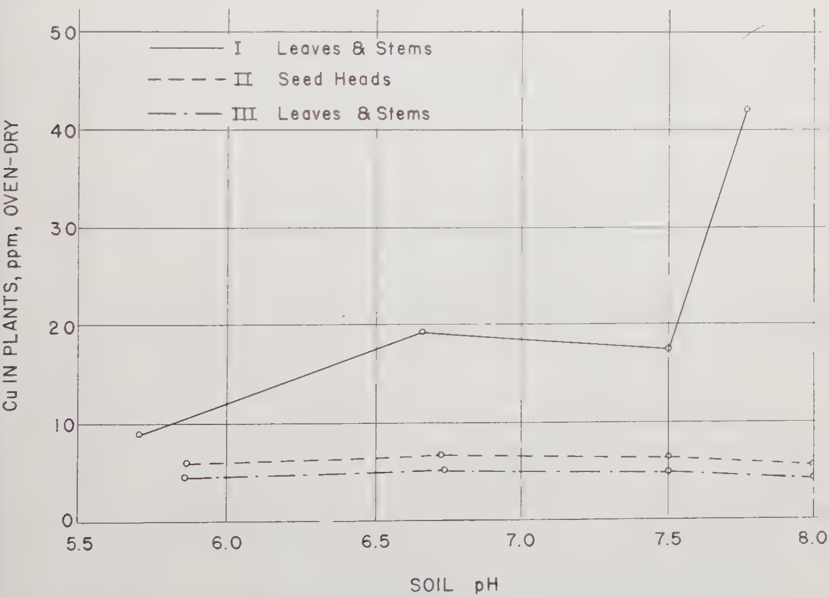

Figure 3.—Copper content of millet at various levels of soil pH where soil treatments contained the equivalent of 1400 pounds P_2O_5 and 50 pounds copper sulfate per acre. (Curve I first sampling. Curves II and III second sampling.)

In Table 3 it is indicated that when copper sulfate is added at the rate of 50 pounds per acre (of bluestone) to a normal, high-level phosphorus treatment, an increase of copper in both the plant and leachate follows. However, increasing the copper to 500 pounds per acre of copper

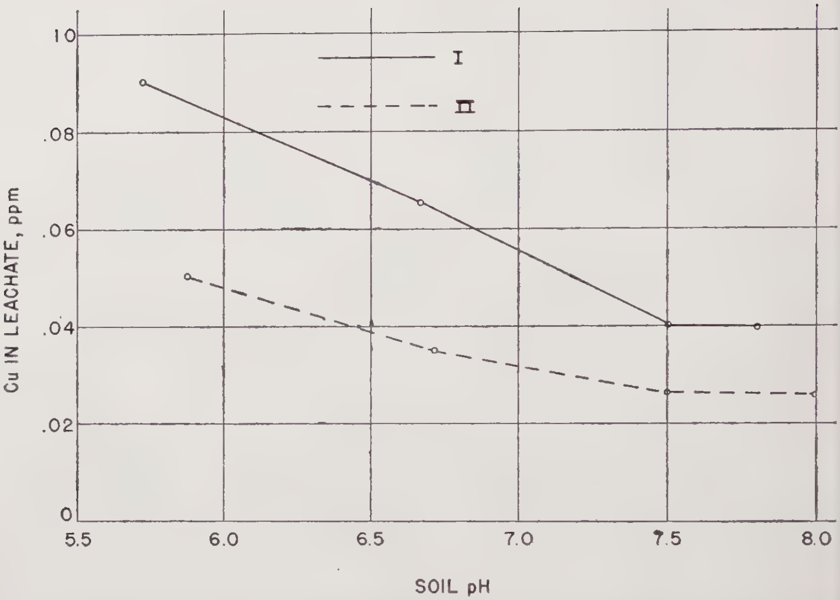

Figure 4.—Copper content of leachate at various levels of soil pH where soil treatments contained the equivalent of 1400 pounds P_2O_5 and 50 pounds copper sulfate per acre. (Curves I and II are for first and second samplings, respectively.)

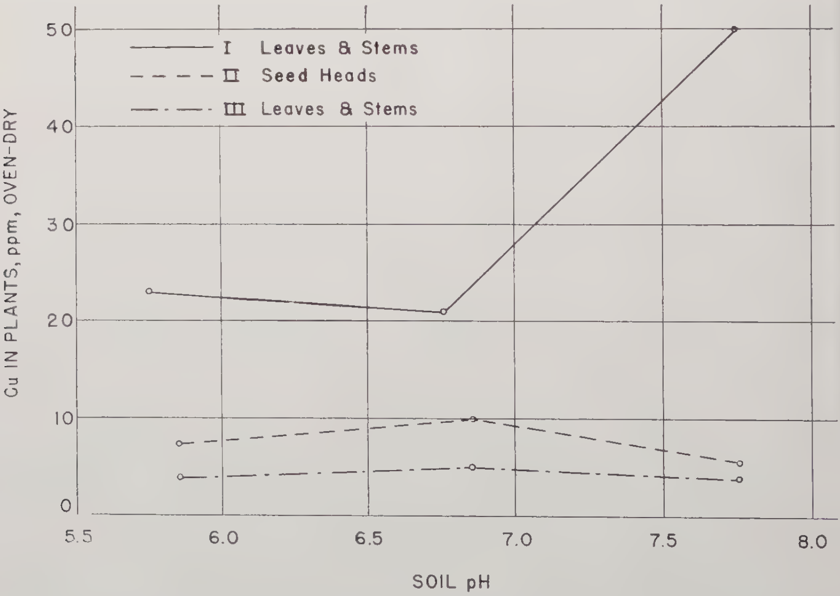

Figure 5.—Copper content of millet at various levels of soil pH where soil treatments contained the equivalent of 140 pounds P_2O_5 and 50 pounds copper sulfate per acre. (Curve I first sampling. Curves II and III the second sampling.)

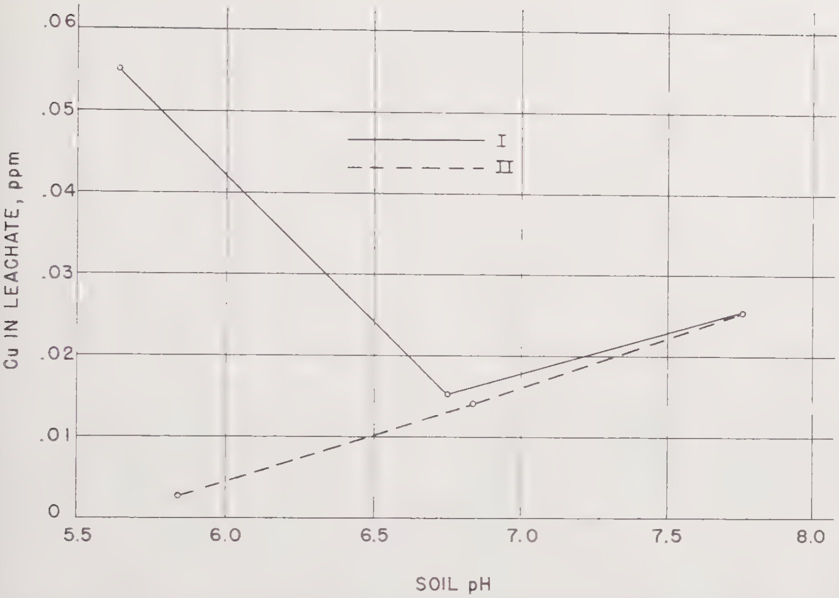

Figure 6.—Copper content of leachate at various levels of soil pH where soil treatments contained the equivalent of 140 pounds P_2O_5 and 50 pounds copper sulfate per acre. (Curves I and II are for first and second samplings, respectively.)

sulfate in this treatment showed little or no effect on the plant although the amount of copper in the leachate continued to increase.

In Figure 7 it is readily observed that varying the application of calcium hydroxide to the soil affects the leaching of phosphorus at the time of the second sampling very much the same as it does copper.

TABLE 3.—Variation of Copper in Plants and Leachates at Three Different Levels of Copper Treatment. All Treatments Include 1400 Pounds P_2O_5 and 0.8 Tons Lime per Acre. (Soil pH between 6.5 and 7.0.)

Copper Sulfate per Acre (Lbs.)	Copper in Leachate (p.p.m.)		Copper in Millet (p. p. m.)*		
			First Sampling	Second Sampling	
	First Sampling	Second Sampling	Leaves and Stems	Leaves and Stems	Seed Heads
0	.010	.003	5.6	3.2	3.4
50	.065	.035	19.0	4.0	5.2
500	.185	.140	20.0	5.0	5.1

* Oven Dry Basis.

The only significant variation in the yield data for the whole experiment was a slightly lower value from the treatments which received no calcium hydroxide. However, there are to be observed two general trends, both of which are somewhat contrary to what one might expect.

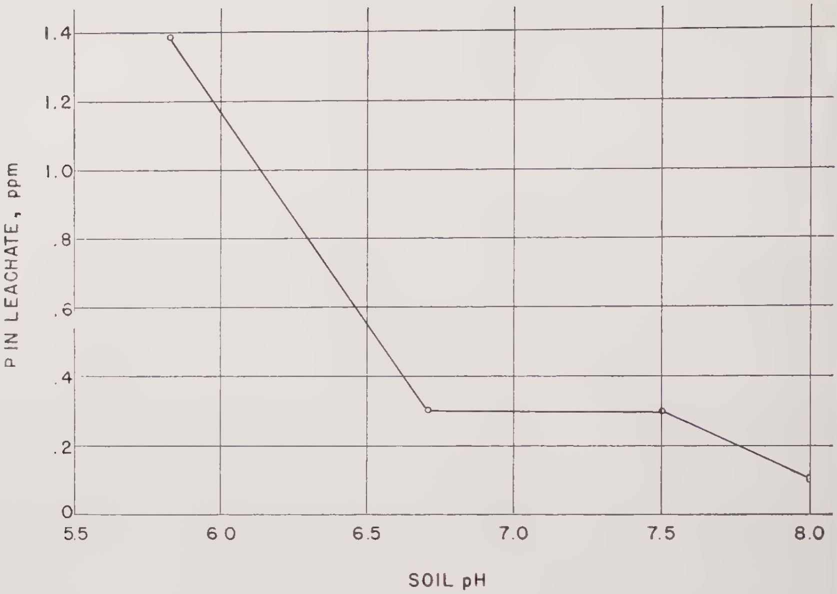

Figure 7.—Phosphorus content of leachate at various levels of soil pH where soil treatments contained the equivalent of 1400 pounds P_2O_5 and 50 pounds copper sulfate per acre. These samples were taken at the second sampling and are the same as those used for Curve II in the preceding graph. This second sampling was eight and a half months after soil treatment.

TABLE 4.—The Effect of Phosphorus and of Calcium Hydroxide on the Assimilation of Copper by Plants and Its Leaching under the Conditions of This Experiment.

Soil Treatment	Trend of Copper	
	In Plant	In Leachate
Mono-calcium Phosphate	down	up
Calcium Hydroxide	up	down

A further consideration of the interactions represented by these two trends is of considerable interest. In Figure 3 it is apparent that the effect of the calcium hydroxide on the copper content of the plant at the time of the second sampling is much less, if present at all, than at the time of the first sampling. This would seem to indicate that the tendency of calcium hydroxide to cause an increase of copper in the plant is no longer active at the time of the second sampling. This, of course, could account for most of the variations between Curve I and Curve III in Figure 1. The differences between Curves I and III for both Figure 1 and Figure 3 are about the same when the pH range is the same. Thus it would seem

that within the limits of the treatments used, greater effects were produced on copper content of the plants by calcium hydroxide than by mono-calcium phosphate though the influence of the phosphate appeared to be more persistent.

This experiment has involved only one soil type and one plant type during one season. There is a very real need for additional data to determine whether or not these trends are fairly general and would be duplicated under different conditions. The same plant response to phosphorus already has been observed [3] where the phosphorus was applied to organic soils as superphosphate and the plant was citrus. Furthermore, the same soil response to both phosphorus and lime has been demonstrated by Jamison [4] on several soil types.

SUMMARY

It seems that two general trends of reaction are evidenced by the data developed under the conditions of this experiment. First, increasing phosphorus in the soil treatments decreases copper in the plant and increases copper in the leachate. This is true for the leachate only up to a certain level of phosphorus beyond which leaching is depressed. Second, increasing calcium hydroxide in the soil treatment increases copper in the plant and decreases copper in the leachate with some exceptions especially where phosphorus treatments were low. During the entire period of the experiment the total copper leached from any treatment was less than 1 percent of the copper added.

[3] Loc. Cit.

[4] Loc. Cit.

NUTRITION OF THE PEANUT PLANT (ABSTRACT)

Dr. Henry C. Harris and Dr. Roger W. Bledsoe *

Fertilizer treatments generally have had relatively little effect on peanuts. The reason for that type of result may be due to any one or more of the following: (1) the plant might have a low requirement, (2) the soil might be well supplied, (3) the experimental technique might be faulty, (4) the fertilizer might not be supplied at the right time or in the right way, and (5) the plant might have an unusual absorptive system capable of supplying itself under almost any conditions. Chemical analyses indicate that the peanut plant contains large amounts of minerals and peanut soils usually are not too fertile, so the first two points have to be discounted. The experimental technique may be faulty because until recently little attention has been given to the nuts left in the soil in the harvesting process. Recent evidence indicates that as many peanuts may be left in the soil after harvesting, in some cases, as are harvested. Placement of fertilizers has had little effect. However, in some cases, gypsum seems to give better results when applied to the tops of the plants at early blooming time. The peanut does have an unusual absorptive system. Both the roots and pegs, or gynophores, grow in the soil, and as early as 1895, Pettit [1] indicated that the pegs had root hairs and suggested that the pegs were a part of the absorptive system.

The fundamental studies reported in this paper were begun with the hope of throwing some light on the inconsistencies of peanut fertilizer results. The experiment was designed to show the relative importance of the roots as compared to the pegs in the absorption and utilization of nutrients. The technique for growing the plants was a special one developed for the purpose that is believed to be new. Each plant was grown in a single gallon glass jug which completely isolated the fruiting or pegging zone from the roots of the plants. This made it possible to supply nutrient solutions to the rooting zone or to the pegging zone separately or in combination. A complete nutrient solution was supplied to the rooting zone of all the plants for 75 days after germination until 30 or more pegs were established. At the end of that period different nutrient treatments were begun. One hundred and thirty days after germination the plants were harvested.

The treatments greatly influenced flowering and peg production. The various deficient solutions except minus sulfur produced striking foliage deficiency symptoms and with the exception of minus potassium lowered the yields of nuts. Plants grown with a complete nutrient solution in the rooting zone, only, had nice foliage but produced no nuts. Normal nut production occurred only where there was a complete nutrient solution in both the rooting and pegging zones. A full explanation of the results will have to await chemical analysis and other data but gross characteristics

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[1] Pettit, Anna S. Arachis hypogaea L. Torrey Bot. Club, 4 (No. 4) 1895.

suggest the following: potassium and sulfur are absorbed by the peanut fruit and are more easily translocated to other parts of the growing plant than the other elements. Calcium, some of the micronutrients, phosphorus, and magnesium may be absorbed by the growing fruit, but they do not seem to be translocated in appreciable quantity to the vegetative portion of the plant. It appears that the root is the primary absorbing region, but because of poor translocation of some of the minerals from the plant to the growing fruit the demand for the elements by the fruit is in excess of the supply and the fruit is capable of absorbing those elements in sufficient quantity to meet its demand.

These results raise the question as to whether it might not be possible to approach the peanut fertilizer problem in other ways.

THE RELATION OF FOLIAGE AND FRUIT ANALYSES TO THE FERTILIZER REQUIREMENTS OF CITRUS

DR. B. R. FUDGE *

INTRODUCTION

The fertilizer requirements for citrus from the viewpoint of practical citrus culture; that is, the amount and quality of fertilizer needed, undoubtedly rests upon several important factors other than the nutrient requirements of the foliage and fruit. The variations in natural fertility of soils and the degree to which nutrients are leached from them are important factors to consider as evidenced by the amounts of fertilizer applied annually to the hammock soils as compared with the light sandy soils of Florida. The manner of fertilizer distribution and the spacing of the trees are important factors in determining the amount to apply per tree. Thus the amount and quality of fertilizer to apply is a question uppermost in the minds of growers, especially those growers who have groves located on the light sandy soil types where large amounts of fertilizer are needed and leaching is rapid.

It is the purpose of this paper to show the degree to which foliage and fruit analyses reflect the amount (intensity factor) and the kind (quality factor) of fertilizer nutrients absorbed by the tree. Due to the limited time allotted, this discussion will be confined to results showing the relationship or balance between calcium, potassium and magnesium as contained in data obtained from plots receiving widely different treatments located on Norfolk sandy soils at the Citrus Experiment Station.

FOLIAGE COMPOSITION

Vegetative growth responses in citrus are normally observed to occur at each of three distinct periods—spring, summer and fall. The spring "flush" of growth is perhaps the most profuse and of greatest importance since it conforms with the period of fruit bud differentiation and the setting of a new crop. Both the time of appearance and the profuseness of growth at each of these periods may be sharply modified by temperature, moisture and combinations of both.

Since citrus is an evergreen tree, its foliage at any given time is composed of many flushes of growth some of which may be three years old. The chemical composition of citrus foliage changes somewhat with increase in age. Therefore, it is important in making comparative analytical studies of the effect of fertilizer treatments that comparable samples of foliage of the same flush and age be obtained from all fertilizer treatments in order to reduce to a minimum the variation within each sample. It is rather difficult to determine the age of foliage produced prior to the current year. Therefore, all of the analytical work presented in this paper was obtained from foliage produced in the spring of the same year in which the samples were collected.

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1. The effect of different rates of calcium and magnesium with a constant rate of Potash (8% K_2O) fertilization.

The use of magnesium bearing fertilizers in recent years has resulted in a most favorable response by the trees as measured by vegetative growth and crop production. In January 1937 an experiment (Block X) was started using fertilizer supplements of different sources of magnesium with a basic 4-6-8 (N-P-K) fertilizer without secondaries. This basic fertilizer is essentially the same as those generally used in the State for many years prior to the time magnesium deficiency was identified. Calcium carbonate treatments were also made for comparison with the magnesium sources. All supplement treatments were applied the last week of January of each year.

a. Magnesium Carbonate ($MgCO_3$)

The results obtained with magnesium carbonate (25% Mg), a very fine precipitated white powder, are given in Table 1. The 1938 results were obtained on growth produced after the second annual treatments; and those for 1940 on growth produced after the fourth and last annual treatments. These results are essentially the same for both sampling periods. Likewise the results obtained in 1939, although not here included, are in close agreement with these two years. The widest differences are found in the composition of the checks (O $MgCO_3$) which is probably related to the effect of the crop in producing magnesium deficiency. The magnesium content of the foliage increases rapidly and to a high level as the amounts of $MgCO_3$ applied increase. The abundant healthy green foliage which was free at all times of patterns of magnesium deficiency gave visual indications that magnesium was being absorbed. However, no amount of visual study or soil analyses would have shown what happened to the calcium and potassium. These two elements decreased in the composition as the magnesium increased—the greater decrease occurring with calcium. In fact the sum of the decreases in calcium and potassium is approximately equal to the total increase in magnesium so that the sum total milliequivalents of Ca plus K plus Mg in the foliage remained almost constant. It is quite apparent that the magnesium carbonate treatments resulted in the absorption of magnesium by replacement and not by addition to the ash constituents of the leaves. Thus the quality of the composition was changed as regards the ionic balance of these three elements while the sum of the three remained approximately the same quantity.

b. Dolomite ($CaCO_3$ 50%, $MgCO_3$ 36%)

The results where dolomite was used are similarly shown in Table 2. This material contains approximately 36 per cent $MgCO_3$ and 50 per cent $CaCO_3$, thus analyzing about 10 per cent magnesium. It is extensively used on light sandy soils to control soil pH between 5.5 and 6.0 and to supply magnesium and calcium to the trees. The amounts applied in this experiment extend considerably above normal grove application of 800 to 1000 pounds per acre. These results show that the absorption of magnesium by the trees increases considerably up to the 800 pound rate of application. Above this amount the rate of absorption falls sharply in relation to the amount applied. This is probably due to the lower solubility of dolomite at the resulting higher soil pH values as rates of application increase and

TABLE 1.—The Effect of Magnesium Carbonate Soil Applications upon the Calcium, Potassium and Magnesium Content of Excelsior Grapefruit Foliage with Graphs (Figs. 1 and 2) Showing the Results for Each Harvest.

Milliequivalents per 100 grams dry leaves.

Annual $MgCO_3$ Treatment	Harvested July 20, 1938				Harvested July 30, 1940			
	Ca	K	Mg	Total	Ca	K	Mg	Total
0*	169.4	61.9	29.9	261.2	158.1	61.8	17.9	237.8
100	157.0	67.6	41.5	266.1	164.1	55.0	30.1	249.2
200	147.8	59.9	41.6	249.3	153.6	50.3	36.8	240.7
400	135.5	60.0	55.1	250.6	143.0	52.8	49.8	245.6
800	129.3	49.0	80.4	258.7	127.2	45.1	79.3	251.6
1600	109.2	54.3	85.7	249.2	106.6	42.6	89.0	238.2

* Average of four checks.

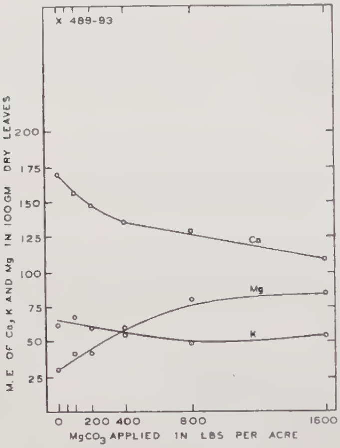

Figure 1
July 20, 1938

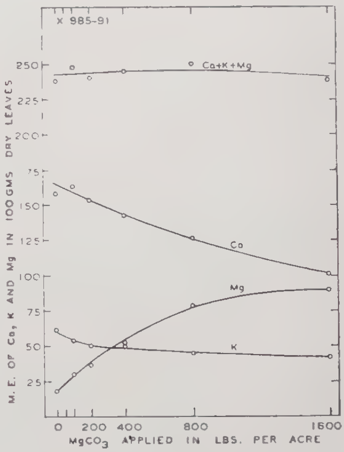

Figure 2
July 30, 1940

to the repressive effect of the calcium ions available for absorption upon absorption of magnesium by the trees (Figs. 3 and 4). The results of the sampling in 1938 show that the calcium ion absorption was apparently unaffected by the calcium carbonate in the dolomite. Two years later after the fourth annual application the absorption of calcium is generally greater than that shown by the check treatment. Likewise, the absorption of magnesium in 1940 was somewhat lower than in 1938, which indicates that calcium and magnesium are balancing each other in absorption by the trees. That this is not due to cropping will be shown in the results with calcium carbonate.

The potassium application is held constant at 8 per cent in the mixed fertilizer applied. Thus it is quite apparent that potassium absorption decreased as the rate of dolomite applied increased. However, the decrease in potassium absorption is about the same with dolomite as with mag-

TABLE 2.—THE EFFECT OF DOLOMITE SOIL APPLICATIONS UPON THE CALCIUM, POTASSIUM AND MAGNESIUM CONTENT OF EXCELSIOR GRAPEFRUIT FOLIAGE WITH GRAPHS (FIGS. 3 AND 4) SHOWING THE RESULTS FOR EACH HARVEST.

Milliequivalents per 100 grams dry leaves.

Annual Applications Dolomite lbs/acre	Harvested July 20, 1938				Harvested July 30, 1940			
	Ca	K	Mg	Total	Ca	K	Mg	Total
0*	169.4	61.9	29.9	261.2	158.1	61.8	17.9	237.8
200	182.0	53.1	34.2	269.3	155.4	54.7	21.5	231.6
400	168.9	59.5	35.9	264.3	168.0	50.2	31.0	249.2
800	167.0	53.3	43.5	263.8	169.7	52.3	36.1	258.1
1600	165.9	52.3	41.7	259.9	163.6	47.9	40.5	252.0
3200	161.0	55.5	49.1	265.6	178.2	53.3	41.0	272.5
6400	172.8	54.2	46.5	273.5	167.6	52.8	39.1	259.5

* Average of four checks.

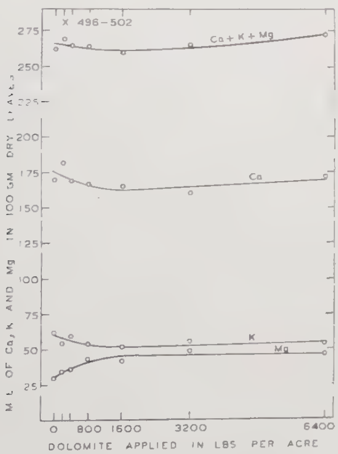

Figure 3
July 20, 1938

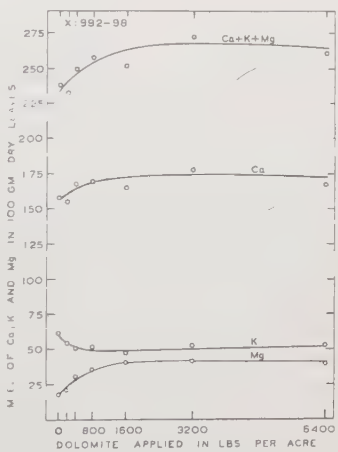

Figure 4
July 30, 1940

nesium carbonate (Table 1). This can be attributed to the lower absorption of magnesium from dolomite being off-set by nominal increases in the absorption of calcium which actually decreased where magnesium carbonate was applied (Figs. 1 and 2). It will be noted that the milliequivalent sum of these elements in 1938 are respectively greater, with one exception, than in 1940. The largest differences in the sums occur in the check treatments and in the low rates of dolomite application. Seasonal variation, especially as regards calcium absorption which appears to be influenced by moisture, may account for the difference between the sums.

c. Calcium Carbonate ($CaCO_3$)

The rates of application of calcium carbonate are the same as those of dolomite. The results are given in Table 3. The trees in these plots were

at the time in a very poor condition due to the deficiency of magnesium, the soil supply of which was very low at the beginning of the experiment in 1937. Of course the condition was aggravated by the additions of calcium carbonate which accentuated the already wide Ca/Mg ratio in the soil and gave rise to the general appearance commonly observed in "over-limed" groves.

The absorption of calcium by the trees was quite apparent from the analyses made in 1938 and much more so in 1940. In fact the milliequivalents of calcium absorbed (266.6) in 1940 after four annual applications each of 6400 pounds of calcium carbonate per acre is approximately equal to the sum (Ca plus K plus Mg) absorbed in 1938 at about the same time of year. Calcium appears to be slow in reaching contact with the roots. In 1940 the soil of plots receiving the larger rates of application were above

TABLE 3.—THE EFFECT OF CALCIUM CARBONATE SOIL APPLICATIONS UPON THE CALCIUM, POTASSIUM AND MAGNESIUM CONTENT OF EXCELSIOR GRAPEFRUIT FOLIAGE WITH GRAPHS (FIGS. 5 AND 6) SHOWING THE RESULTS FOR EACH HARVEST.

Milliequivalents per 100 grams dry leaves.

$CaCO_3$ Application lbs/acre	Harvested July 20, 1938				Harvested July 30, 1940			
	Ca	K	Mg	Total	Ca	K	Mg	Total
0*	169.4	61.9	29.0	261.2	158.1	61.8	17.9	237.8
200	188.3	54.3	28.5	271.1	164.7	60.9	14.1	239.7
400	191.1	54.1	24.2	269.4	170.0	57.9	15.0	242.9
800	205.4	48.4	24.2	278.0	191.7	50.7	16.9	259.3
1600	200.0	51.4	24.8	276.2	223.6	48.6	17.9	290.1
3200	192.4	54.9	21.3	268.6	238.5	51.3	16.5	306.3
6400	199.9	52.2	24.5	276.6	266.6	46.2	20.0	332.8

* Average of four checks.

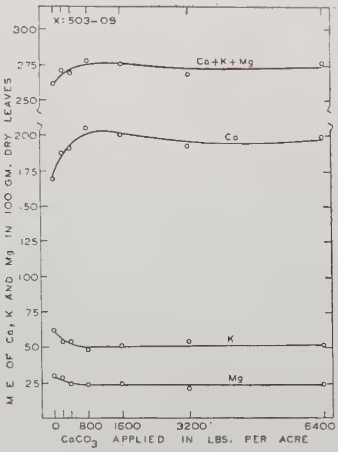

Figure 5
July 20, 1938

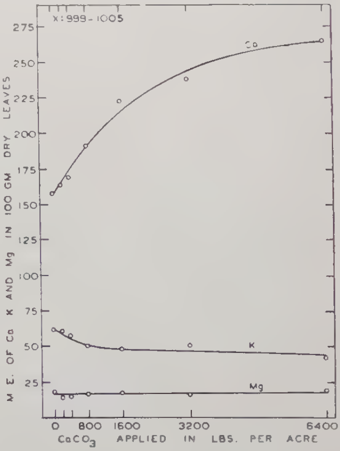

Figure 6
July 30, 1940

pH 7.0 and there was an excess of free $CaCO_3$ present. It is conceivable that the fibrous roots came into direct contact with the solid phase of calcium carbonate thereby enhancing calcium absorption. The effects of organic matter which is very low in this soil and the organic acids are not considered to have had much influence in bringing the calcium into solution. The effects of the acid N-P-K fertilizer and sulfur residues from spray material may have had some influence.

The repressive effect of calcium carbonate upon potassium absorption from 8 per cent fertilizer is quite evident in the results for both years, especially in 1940 (Figs. 5 and 6). It is interesting to note that the repressive effect upon magnesium is not so great due apparently to the severe deficiency of this element in these plots. Although the results with dolomite showed some indication, especially in 1940, of an increase in the milliequivalent sum (intensity factor) of these three elements in the foli-

TABLE 4.—The Effect of Muriate of Potash Applications in Mixed Fertilizers upon the Calcium, Potassium and Magnesium in Valencia and Hamlin Orange Foliage with Graphs (Figs. 7 and 8) Showing the Results for Each Harvest.

Milliequivalents per 100 grams dry leaves.

Unit of K_2O in Fertilizer	Harvested August 4, 1943				Harvested August 23, 1945			
	Ca	K	Mg	Total	Ca	K	Mg	Total
0	176.6	35.0	47.0	258.6	124.2	50.4	48.6	223.2
2.0	160.5	49.0	38.4	247.9	110.8	62.4	40.8	214.0
5.0	142.2	58.7	34.9	235.8	115.1	68.8	41.6	225.5
8.0	137.5	62.3	32.4	232.2	105.2	73.4	37.6	216.2
10.0	127.2	67.8	27.7	222.7	99.8	78.0	38.5	216.3
12.0	131.5	67.7	26.4	225.6	95.0	82.5	33.3	210.8
16.0	116.8	75.2	23.4	215.4	93.2	88.4	31.7	213.3

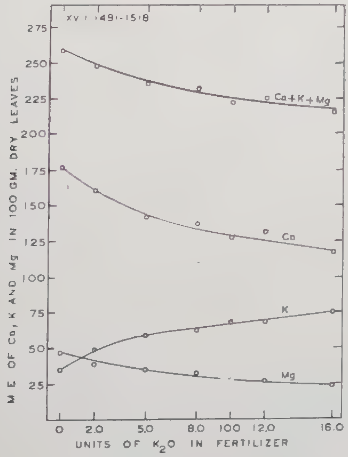

Figure 7
August 4, 1943

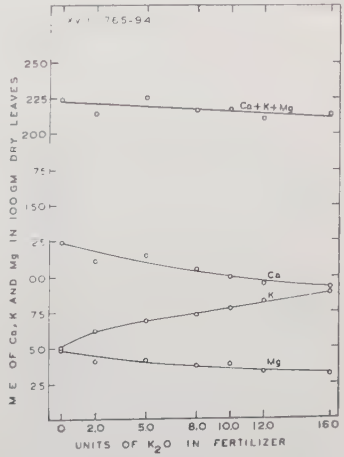

Figure 8
August 23, 1945

age, the intensity of composition where calcium carbonate is applied increases as the application of this material increases. This must be due to the calcium absorbed since both potassium and magnesium decrease or remain quite constant in the foliage. The results presented thus far have shown the effects which supplements of magnesium, calcium, and a mixture of the two (dolomite) have exerted upon leaf composition.

2. The effect of different rates of Potash Fertilization with constant treatments of calcium and magnesium.

In all of the above treatments potassium application was a constant at 8 per cent in the mixed fertilizer. The results given in Table 4 show the effect of varying the amount of potassium applied while holding the calcium and magnesium at a constant treatment in all plots. Although the Valencia and Hamlin trees in these plots were only six years old in 1943, they were bearing some crop. Foliage samples of each variety were analyzed separately, but for the purpose of this paper the results have been averaged. Thus the data given in Table 4 are averages of four analyses since the treatments are made in duplicate (Block XVII).

The absorption of potassium as measured by foliage analyses increased as the amount of available potassium in the soil was enhanced by fertilization. The trees of both varieties showed no visual response in either foliage or fruit to the increases in potassium absorption. Since these are young trees and have had a comparatively low crop requirement for these elements, it is possible that the available potassium in the checks was still above the threshold of a deficiency. In spite of the fact that the absorption of calcium was comparatively low in all plots, and the absorption of magnesium quite high, the effect of the increases in absorption of potassium was to materially reduce the uptake of both calcium and magnesium to such an extent that the total decrease of calcium plus magnesium was greater than the increase in potassium which explains why the milliequivalent sum of these elements decreased with increases in absorption of potassium (Figs. 7 and 8). In this regard these results are similar to those obtained with magnesium (Table 1) (Figs. 1 and 2). The difference in the results shown in Figure 7 as compared to those in Figure 8 illustrate the significance of ionic balance in nutrient absorption. Thus, results for calcium are relatively high in 1943 as compared with those found in 1945; whereas, potassium and magnesium are respectively lower in 1943. Therefore, when the respective composition curves of each element are plotted, the slopes of the lines are almost parallel showing that the only difference in the results for the two years is in the intensity of composition at the moment of sampling.

3. The effect of different rates of Potash fertilization at two different levels of treatment with calcium and magnesium.

The results in Table 5 show the relation of potassium absorption at different rates of application as influenced by calcium and magnesium at two different levels obtained by applying dolomite and soluble magnesium across a section of the plots at right angles to the potash treatments. The Duncan grapefruit trees in these plots (Block V) are among the oldest on the Station property and have been used for many years for potassium studies. In the fall of 1939 the fertilizer treatment applied on plot No. 6 was changed from a variable 3% in Spring, 5% in Summer and 10%

TABLE 5.—THE EFFECT OF MURIATE OF POTASH APPLICATIONS IN MIXED FERTILIZERS WITH AND WITHOUT SUPPLEMENT APPLICATIONS OF CALCIUM AND MAGNESIUM UPON THE AMOUNTS OF THESE ELEMENTS FOUND IN DUNCAN GRAPEFRUIT FOLIAGE WITH GRAPH (FIG. 9) SHOWING THE INFLUENCE OF THESE ELEMENTS.

Milliequivalents per 100 grams dry leaves.

		Units of K_2O in Fertilizer			
		0	3	5	10
Low Ca and Mg (A) Soil pH 4.7-5.0	Ca	230.7	191.8	156.4	158.3
	K	29.9	54.2	81.5	87.0
	Mg	12.9	14.2	8.9	10.9
	Total	273.5	260.2	246.8	256.2
Added Ca and Mg (B) Soil pH 5.5-6.0 (Dolomite & soluble Mg)	Ca	245.9	217.2	216.1	184.0
	K	30.8	45.7	60.5	77.3
	Mg	29.0	34.9	26.2	27.0
	Total	305.7	297.8	302.8	288.3

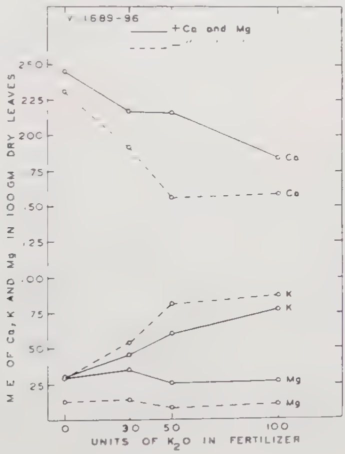

Figure 9

K_2O in Fall to a check (No K_2O). At the same time the calcium and magnesium treatments were applied across a section of the potash plots. The effect of crop production upon the general appearance of these trees gives an excellent comparison of the old acid type of fertilization program (A) as compared with the new less acid type of fertilization program (B). The trees in the section of plots (B) receiving added calcium and magnesium have much more foliage and generally are in a much better physical condition as a basis for crop production.

These data are in agreement with those presented in Table 4 in showing the effects of potassium upon the absorption of calcium and magnesium; that is, as the absorption of potassium increased, the absorption of calcium and magnesium decreased, especially calcium. Even in the low calcium and magnesium section (A) the trees in the no potash plot produced leaves which contained 230.7 M. E. of calcium which is equal to approximately

4.6 per cent of calcium in the dry leaves. Under no other conditions have so large amounts of calcium been found in foliage on trees located on sandy soils of pH 5.0 and having only super-phosphate as a source of calcium. None of the dolomite treatments (Table 2) and only the highest calcium carbonate treatments (Table 3, 1940) were able to produce foliage in the presence of 8 per cent K_2O fertilizer containing as much calcium. Of course, the highest level of calcium (245.9 M. E.) found was in the corresponding no potash plot where calcium and magnesium had been applied (B). The difference in these two values (245.9 - 230.7) is only about 15 milliequivalents of calcium. However, the differences in calcium absorption became slightly greater as the amounts of available potassium increased (Fig. 9). The addition of calcium and magnesium supplements (B), without exception, has increased the absorption of these two elements and has repressed the absorption of potassium at each of the levels at which it is applied. Therefore, these results agree with those already presented in showing the significance of the cation balance of these three elements. In fact, these results show that nutrient balance is as important in nutrient absorption as is the concentration of the element. Certainly there can be no fixed level in the quantity of any one of these cations in the soil which may be considered as an "adequate supply" for the tree without due consideration of the balance in the supply of the other two elements.

The potassium content of the Duncan foliage was approximately 30 M. E. where no potassium had been applied since summer of 1939. This amount is slightly lower than the amounts found in the foliage on young Hamlin and Valencia orange trees similarly treated (Table 4) and is considered to be a deficiency level of potassium as indicated by the comparative appearance of the Duncan trees and the dropping of fruit in the no potash treatments. The young orange trees are not yet showing any deficiency symptoms. In making comparisons of the potassium content in the foliage of similarly treated plots in these two experiments several important factors must be considered; namely, repressive effects of different levels of calcium and magnesium, differences in the amounts of fertilizer applied per tree, effect of cropping and to some extent the differences due to varietal response of oranges and grapefruit. The data show that calcium is higher in the grapefruit foliage; whereas magnesium is higher in the orange foliage. It has already been shown that application of these elements produced a repressive effect upon potassium absorption with calcium exerting a somewhat greater influence. In addition to these factors the actual amount of K_2O applied to each Duncan tree during any single year was 75 to 80 per cent greater than the amounts applied to trees in analogous plots in the experiment with oranges. In spite of these differences, the data from these two experiments (Tables 4 and 5) are in good agreement and illustrate the significance of ion balance in the nutrient supply to ion absorption by the trees.

FRUIT COMPOSITION

The effect of crop production in inducing the symptoms of magnesium deficiency to appear under conditions of inadequate soil supply has made the citrus grower more conscious of the effects of crop removal of nutrient

elements. With the exception of potassium, amounts of the minerals removed in the fruit are comparatively small as compared with the amounts found in the vegetative parts of the tree especially the amounts found in leaves. Where the supply of an element is inadequate for both vegetative growth and fruit production, the fruit seems to be able to meet its requirements by inducing even acute deficiency of this element in the vegetative tissues.

The data given in Table 6 show the amounts of calcium, potassium and magnesium contained in Duncan whole grapefruit (Block V). Of these three elements, potassium is removed in greatest amount. These data show that the potash content of the fruit increased as the amount applied in the fertilizer increased and the amounts found in the fruit are almost as large as those of the foliage from corresponding plots (Table 5). With nominal potash fertilization the amount of K_2O in the fruit is greater than the combined amounts of calcium and magnesium found (Fig. 10). Even un-

TABLE 6.—Muriate of Potash Applications in Mixed Fertilizer with and without Supplement Applications of Calcium and Magnesium Showing the Effects of These Elements (Fig. 10) upon Fruit Composition.

Milliequivalents per 100 grams of dry whole fruit.

		Units of K_2O in Fertilizer			
		0	3	5	10
Low Ca and Mg (A) Soil pH 4.7-5.0	Ca	29.7	33.6	28.3	25.7
	K	35.2	40.1	48.8	55.7
	Mg	6.2	11.7	8.1	8.2
	Total	71.1	85.4	85.2	89.6
Added Ca and Mg (B) Soil pH 5.5-6.0 (Dolomite & soluble Mg)	Ca	38.8	33.9	31.8	25.5
	K	34.4	43.7	53.6	57.7
	Mg	9.3	10.4	10.4	10.1
	Total	82.5	88.0	95.8	93.3

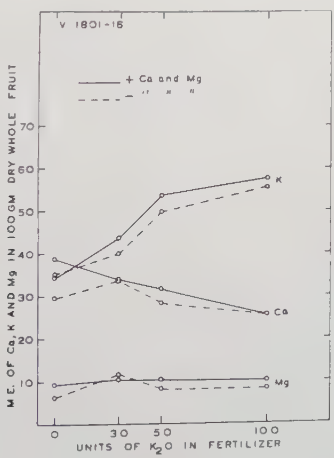

Figure 10

der conditions where no potash has been applied since the summer of 1939, the fruit (1944-45 crop) contains considerable potassium. The independent nature of fruit composition is shown by the data for potassium in that the milliequivalent composition of this element is as high or higher with added calcium and magnesium than without these elements which are known to have a repressive effect upon the accumulation of potassium in the foliage (Fig. 10).

Although the data for calcium content show a slight inverse relationship to potassium content, the magnitude is much lower than that which occurred in the leaves (Table 5). Thus the fruit did not reflect the large absorption of calcium obtained in the leaves where no potash was applied (Fig. 9). The same is true of the magnesium content of the fruit. As a consequence of the high accumulation of potassium in the fruit as compared with calcium and magnesium, the milliequivalent sum of these elements increased as the rate of potash accumulation in the fruit increased. In this regard the accumulation of potassium in the fruit is similar to that of calcium in the foliage. Apparently the solubility and mobility of compounds of these elements within the plant are important factors to consider in studies on fertilizer requirements. It is quite apparent that fruit analyses do not reflect the status of the nutrient supply and requirements of citrus to the extent indicated by foliage analyses. Therefore, the value of fruit analyses as a tool in determining the fertilizer requirements of citrus is questionable. Of these three elements potassium is the only one that will be considered further.

Obviously, the amounts of mineral elements removed in fruit from a tree depends upon the size of the crop more than upon the unit composition. In Table 7 the average yield of fresh grapefruit per tree for a four-year period (1940-44) was compiled for each potash treatment. And on the basis of the analyses shown in Table 6 the total amount of K_2O removed in the fruit was calculated. Likewise the total amounts of K_2O applied in the fertilizer during the same period was computed. The amount applied less the amount removed in fruit gives a measure of the excess potash applied at the different rates of application.

TABLE 7.—Average Four Year Results, 1940-44, Showing Crop Yield per Tree and Potash (K_2O) Removal as Affected by Amounts of Potash Applied to Soil in Mixed Fertilizer with and without Supplements of Calcium and Magnesium.

		Units of K_2O in Fertilizer			
		0	3	5	10
		Pounds	Pounds	Pounds	Pounds
Low Ca & Mg (A) Soil pH 4.6-4.8	Yield of Fresh Fruit	1561	2679	1746	1483
	Dry Matter	205.3	352.3	229.6	195.1
	Total K_2O applied	0.0	7.08	11.80	23.60
	Total K_2O in fruit	3.41	6.64	5.28	5.11
	Difference	—3.41	0.44	6.52	18.49
Added Ca & Mg (B) Soil pH 5.5-6.0 (Dolomite & soluble Mg.)	Yield of Fresh Fruit	2680	1951	3187	2287
	Dry Matter	376.2	256.6	419.1	300.7
	Total K_2O applied	0.0	7.08	11.80	23.60
	Total K_2O in fruit	6.09	5.28	10.58	8.15
	Difference	—6.09	1.80	1.22	15.45

Since the size of crop is the important factor which determines the amounts of these elements removed from a tree, it is quite apparent that section (B) of the plots receiving calcium and magnesium supplements have had more K_2O removed in fruit, with one exception, than was removed where calcium and magnesium were low and symptoms of severe magnesium deficiency were apparent in the foliage. Although calcium and magnesium have been shown to have a repressive effect upon potassium absorption as indicated by foliage analyses (Table 5), these results show that more potassium has been removed with one exception, in fruit where calcium and magnesium were used. This is especially true where no potash was applied and the amounts of K_2O removed in the fruit were in excess. It appears that tree efficiency for fruit production can only be vaguely related to fruit composition as relating to calcium, potassium and magnesium. Nor is the computation of the total crop removal of much value. The efficiency of a tree apparently lies in the amount and quality of its foliage. Therefore, foliage analyses reflect to a much greater degree the nutritional status of the tree.

The fruit is still accumulating considerable potassium even where no potash fertilizer has been applied since the summer of 1939. It was thought that perhaps this potash may be coming from an accumulated reserve in the trees which had received a total of 18 units of K_2O in the fertilizer annually prior to this plot being made a check treatment in 1939.

Samples of the trunk wood were collected in November 1945 and analyzed for potassium for the purpose of detecting any depletion of a reserve nature. The amounts found were very small for all treatments and did not indicate that the fruit accumulation of potassium in the check treatments could be explained as a depletion of the reserve of potassium within the tree. These results indicate that each crop is annually obtaining from the soil the potash which is removed in the fruit.

DISCUSSION

The commercial use of calcium and magnesium supplements in the form of dolomite had its beginning in the early thirties. This was soon followed by the use of soluble salts of magnesium and later by the use of basic oxides and hydroxides of magnesium. These materials are now integral parts of the recommended fertilizer program for citrus which has passed the stage of "deficiency correction" and is now designed as a maintenance program.

Throughout this period the general appearance of citrus groves located on the sandy soils have improved immensely in physical condition as indicated by the presence of abundant, normal green foliage. As a consequence of this improved condition, the yield has been greatly increased. The plots from which the results herein reported were obtained have served as a demonstration to many citrus growers throughout the State of the performance of the fertilizer program now recommended.

The improved physical condition and the better yield performance of the trees are largely the result of changes in the internal composition of the tree which in this paper is measured in terms of foliage and fruit analyses. For the three elements under discussion (Ca, Mg, K) these changes in composition may be grouped into two categories; namely, those

resulting in a change of the "quality of composition" such as changes in ionic balance or ratio, and those resulting in a change of the "intensity" of composition such as changes in the magnitude or quantity of the elements in the ash. In the latter category belong treatments which produce significant changes in the sum total of these elements (Ca+Mg+K). Calcium is the only one of these elements which accumulates in the foliage by addition to as well as by replacements of other mineral constituents.

None of the experimental results indicate that it is possible to induce increases or decreases in the intensity of composition of all three elements changing in a somewhat parallel direction. Thus these results are in agreement with the well known observation of the repressive effect of one element upon the absorption of another. All of the graphs (Figs. 1 to 9) illustrate the influence of ionic balance in the nutrient solution upon ion absorption by the plant. The absorption of magnesium and potassium are somewhat similar in that these elements enter largely by replacement of other elements and do not increase the total ash per unit weight of dry matter (Figs. 1, 2, 7, 8). Thus the milliequivalent increases of either magnesium or potassium is approximately equal to the milliequivalent decreases in the other two elements. Although calcium repressed the absorption of both magnesium and potassium, it continued to be absorbed beyond the milliequivalent replacement of these two elements and thereby resulted in increases in the total ash content of these elements (Sum Ca + Mg + K) in the dry matter (Figs. 5 and 6).

Since dolomite is composed of a mixture of calcium and magnesium carbonates, it is a good source of both calcium and magnesium. At the same time it serves to correct and maintain the soil reaction in the recommended range of pH 5.5 to 6.0. However, the data (Table 2, Figs. 3 and 4) indicate that absorption of magnesium from dolomite does not increase proportionately with increased rates of application. In fact above applications of 800 pounds per acre, the magnesium content of the foliage was not significantly increased. Since the soil reaction in the check plots was approximately pH 4.8, it is conceivable that the rates of application below 800 pounds per acre reacted with the acid soil and produced active (soluble plus exchangeable) magnesium. Likewise had this experiment been started on grove soils already in the desired pH range, magnesium absorption from dolomite may have been negligible even at the lower rates of application. Thus it is recommended that sources of water soluble magnesium be included in the fertilizer mixtures even where dolomite has been applied in a maintenance program. Due to applications of dolomite over the past ten years many citrus grove soils now have a pH value of approximately 6.0. Therefore one should not expect to obtain much absorption of magnesium from this source under such conditions. However, the sandy soils over a period of a few years will drift downward in pH as a result of leaching of bases and the application of acid fertilizer materials. Thus dolomite is extensively used to control the downward drift of the soil reaction and to supply slowly active magnesium.

Although it is generally recognized that some of our best citrus is grown on soil containing a high level of available calcium, these results indicate that a nutrient ion balance which will permit efficient nutrient absorption of all three of these cations is desirable. On high calcium soils

the problem is largely the maintenance of proper levels of magnesium, potassium and trace metallic elements for efficient fruit production. In certain areas where the soil is extremely high in calcium the problem of maintaining a good nutrient balance is acute and the tree condition is usually poor. For the same reason the additions of large amounts of calcium lime to the poorly buffered sandy soils of low exchange capacity is not recommended because of the repressive effects upon the absorption of magnesium and potassium and the reduction in the availability of the trace elements. However, these results indicate that it should be possible, in spite of leaching, to devise a fertilizer program for the light sandy soil types which would permit maximum calcium absorption without inducing the ill effect of "overliming". Since potassium greatly affects the absorption of calcium (Figs. 7 to 9), these data point to the lowest efficient level of potash fertilization as a means of inducing higher calcium absorption without excessive applications of calcium lime. There is need for more experimental evidence on this point.

All of the results on these and other plots not reported in this paper show that the absorption of potassium has been repressed where calcium and magnesium have been added to the soil. The absorption of potassium by trees on plots receiving 10 per cent K_2O in the fertilizer in the presence of added calcium and magnesium (Fig. 9) is approximately the same as those in plots receiving 5 per cent K_2O with low levels of calcium and magnesium. Thus the new fertilizer program has unwittingly brought about a lower efficiency in the absorption of potash due to the presence of added calcium and magnesium.

With the exception of potassium the mineral content of fruit is quite low as compared with foliage composition. As a consequence, fruit analyses do not show the nutrient requirements of citrus so well as do foliage analyses. However, computations of the amounts of elements removed in the average crop per tree does reflect the degree of efficiency of the treatment in converting these elements into fruit. Of course this depends upon the amount of fruit produced per tree in any one year or over a period of years. Results based upon one crop year are very unreliable because of the many factors other than the nutrient supply which influence crop production. Since the fertilizer program for citrus is based upon three annual treatments of which one and sometimes two of these are made at times when no fruit is present on the trees, crop production and fruit nutrient removal can be only vaguely used as a basis for a fertilizer program. In the summer when the size of the potential crop becomes apparent and in the fall following a heavy crop, are periods when consideration is given to the amount of fertilizer to apply per tree. Of course in the spring when a profuseness of new growth appears and setting of crop occurs, a liberal application of fertilizer, especially nitrogen, potassium and magnesium is always indicated.

SUMMARY

1. The nutrient balance in light sandy soils of low exchange capacity can be greatly altered by the application of nominal quantities of fertilizer materials to grove soils.

2. Changes in the nutrient balance between calcium, magnesium and potassium induce sharp changes in absorption of these elements by citrus trees.

3. Soil applications of any one of these three elements produce a repressive effect upon the absorption of the other two.

4. Calcium absorption increases above the equivalent replacement of the other two elements thereby significantly increasing the per cent ash in the dry matter.

5. Foliage composition is a more sensitive measure of mineral nutrient absorption than is fruit composition.

APPLICATION OF RAPID METHODS OF LABORATORY ANALYSIS TO EVERGLADES SOILS

DR. W. T. FORSEE, JR. *

In 1938 work was initiated at the Everglades Experiment Station on the use of rapid laboratory methods in the analyses of the peat and muck soils of the Everglades. Certain methods and their adaptability to this type of soil have been discussed in previous publications.[1 2 3]

Nitrogen, phosphorus and potassium are the elements to which rapid laboratory methods have been adapted on Everglades soils up to the present time. The method now in use consists briefly of extraction of ninety-eight samples at a time with 0.5N acetic acid. Nitrogen estimates are made on a spot plate with diphenylamine. Phosphorus is determined colorimetrically by a modified molybdate blue procedure. The sample of soil extract used for potassium determinations is first freed of organic matter and ammonia. The potassium is precipitated in centrifuge tubes with cobaltinitrite, the precipitate washed with alcohol and the cobalt determined colorimetrically with nitroso-R salt. This procedure for potassium is somewhat long to be called a "rapid" laboratory method. However, a large number can be run at one time thus making the actual amount of time spent on each sample rather small. The cobaltinitrite precipitation, washing and color development are all carried out in the same centrifuge tube with no time consumed in transferring aliquots.

The ultimate usefulness of any soil test is determined by the way in which its results correlate with actual plant responses and yields. Hence, the results of soil tests are useful more from the standpoint of their relative values than from their absolute values. For example, if soil tests conducted on samples from a celery fertility experiment show that increased yields will be obtained up to a potassium level of 300 pounds per acre we have the information that we are seeking. Perhaps a quantitative test for exchangeable potassium might indicate 400 pounds per acre as the absolute value for the available potassium in this soil on which maximum yield should be expected. But why spend the time to obtain the absolute value when the relative value as given by the rapid laboratory method can be used just as well in making fertilizer recommendations? In order to utilize soil testing as a practical tool we must have methods by which we can handle large numbers of samples over a reasonable period of time, the results must be reproducible and the relative values found must correlate with plant growth and yields. The correlation of these tests with plant growth and yields is the time consuming phase of the work but the tests can not be safely applied to any crop until such data are obtained. When these data are obtained for any one crop on a certain soil type the "pay-off" comes in practical applications where one knows what he is doing and not feeling his way in the dark. Under Everglades conditions the problem is simplified somewhat by the fact that all the soils are highly

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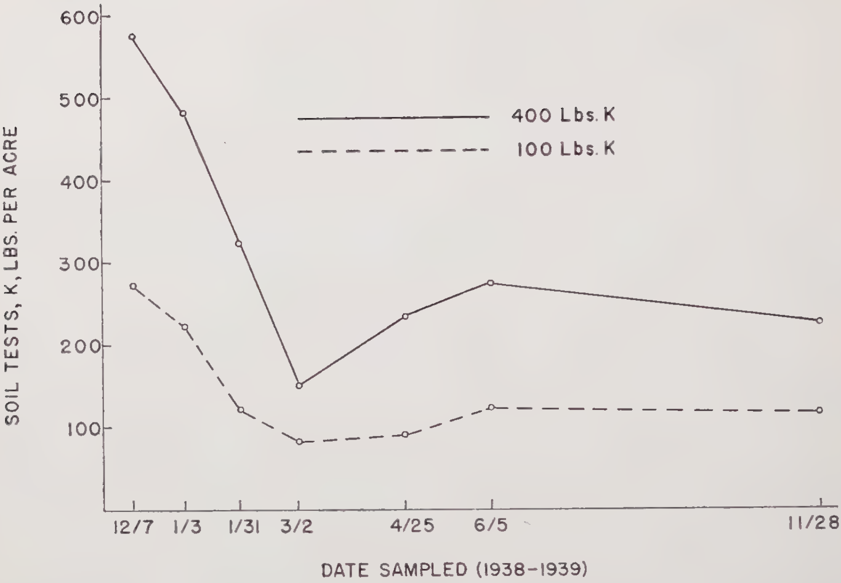

Figure 1.—Potassium levels in soil samples taken at intervals from celery plots receiving potash at two rates of application.

organic and of more or less the same general type. However, pH variations introduce problems which will be considered later in this discussion.

One interesting application of these rapid laboratory methods is the following of the fertility level in the soil under a growing crop. Such an application is presented graphically in Figure 1. The upper curve represents the soil potassium levels as determined by a rapid laboratory method on samples collected from plots receiving a 24 percent K_2O fertilizer applied at 2000 pounds per acre. The lower curve represents the potassium levels in plots receiving 6 percent K_2O fertilizer applied at the same rate. These samples were taken during the last year of a three year fertility experiment on celery. The first sampling, 12/7/38, was made at the time of planting which was about two weeks after the fertilizer was applied. Samples were then taken at approximately one month intervals until harvest on 3/2/39. As the crop advanced in age the soil potassium level decreased more slowly at first and then at an increased rate until harvest. The 24 percent K_2O treatment showed a tremendous drop thus illustrating the capacity of celery to take up tremendous quantities of potassium when available. At the time of harvest the celery was hand stripped in the field according to commercial practice. These strippings were disced into the soil and the replacement of the potassium by their decomposition is shown by samplings on 4/25/39 and 6/5/39. Note the large amount of potassium replaced by the strippings from the celery that had taken up such tremendous amounts during growth. About six months later, after the summer rainy season, samplings were made again and the graph shows the small losses due to leaching.

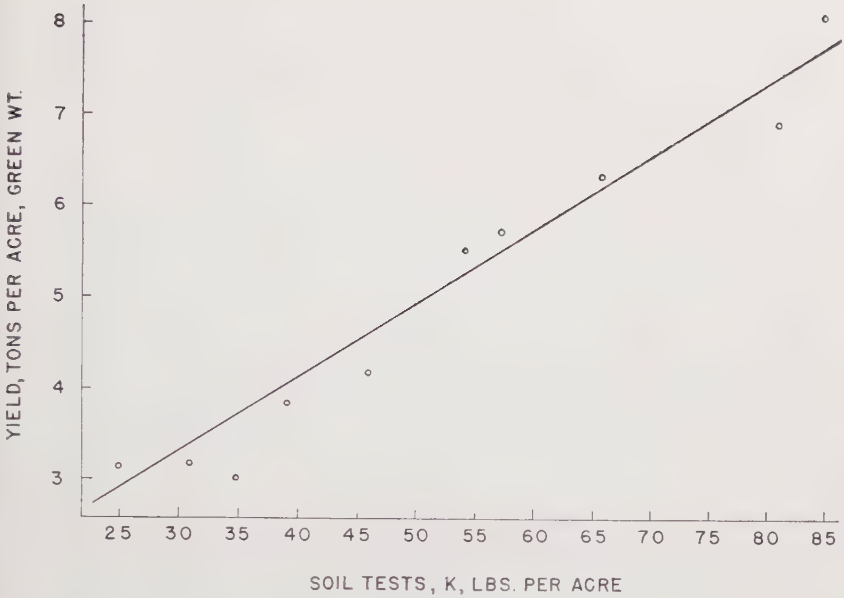

Figure 2.—Correlations of yields of Dallis grass with potassium in soil.

The correlation of yields of Dallis grass with potassium in the soil as determined by rapid laboratory methods is shown in Figure 2. These data were obtained from a series of grass fertility plots. The yield data were furnished by Dr. J. R. Neller. The grass had been mowed and removed from the plots on 4/18/40. The soil samples were taken five days later and analyzed for potassium by a rapid laboratory method. The grass yields were obtained approximately one month later on 5/25/40. Each point in the Figure represents an average of four replicated plots. The curve has been drawn in by observation. There is a definite increase in yield due to increases in potassium in the soil as determined by the tests. These tests indicate that the potassium level on pastures in the Everglades should be maintained at a level of at least sixty-five or seventy pounds per acre.

TABLE 1.—Soil and Tissue Tests on Samples from a Corn Field of a Local Farmer.

Sample Description	Soil Tests		Tissue Tests
	pH	P (lbs. per A.)	P (ppm.)
Very poor corn Strong evidence of P_2O_5 deficiency	7.6	16	49
Good corn Slight evidence of P_2O_5 deficiency	6.8	10	93
Fair corn Some evidence of P_2O_5 deficiency	7.2	20	79

In May of 1942 we were requested by a local grower to observe a field of corn. Part of the field showed very poor growth. By observing the plant symptoms, the Agronomist pronounced the trouble as probably due to phosphorus deficiency. Soil samples were taken. The results of these tests are recorded in Table 1. The soil sample from under the corn which showed the least evidence of phosphorus deficiency was the lowest of all in phosphorus according to the soil test. The plant growth seemed to decrease as the pH increased but there was no correlation between growth and the phosphorus tests. This field had been sprayed twice with manganese and zinc and the plants showed no characteristic symptoms of manganese or zinc deficiencies which frequently occur on Everglades soils at such high pH values. It was then decided to try stem tissue tests. Whole plant samples were collected and brought immediately to the laboratory. Cross sections of the lower portion of the stalks were weighed and extracted in a Waring Blendor with 0.5*N* acetic acid. The filtrate from this was used for testing according to the same procedures employed in soil testing. The phosphorus tests on these plant samples are recorded in Table 1. Here we have good agreement between the tissue tests and the observed growth and deficiency symptoms.

There is no correlation however, between these tissue tests and the soil tests. Assuming that the plant is the better index of nutrient availability, we are led to the conclusion that the soil test for phosphorus is not dependable at pH values above normal. On Everglades soils this normal value is about pH 5.4 to 5.8. This particular experience with corn immediately initiated tissue testing as a companion to soil testing. It has been of tre-

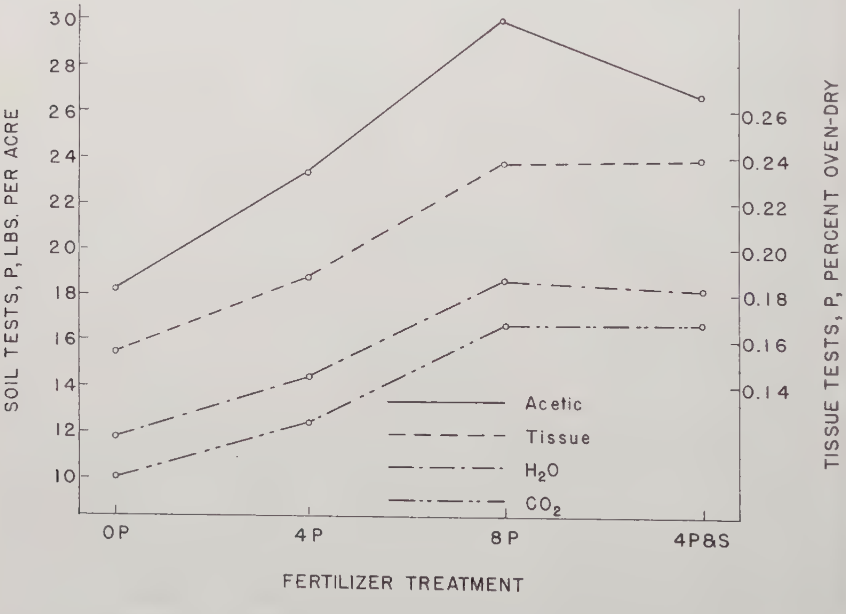

Figure 3.—Relation of phosphorus in stem tissue of celery to that removed from the soil by three different extractions.

mendous aid since that time in the interpretation and evaluation of soil test data.

As already emphasized the relative value of any soil test for phosphorus or any other element depends upon the correlation of the results of the test with actual plant response and the uptake of phosphorus as determined by tissue tests on the plants. Obviously the adaptability of the test to soils of various pH values is dependent upon the choice of the extracting solution. Taking advantage of some fertility experiments on celery where a marked yield response to phosphorus was obtained, some preliminary studies have been made on the relative merits of water, carbonic acid and 0.5*N* acetic acid used as soil extractants. These results are reported graphically in Figure 3. The points 0P, 4P, 8P and 4P+S represent plots that received no phosphate, 2000 pounds of a 4 percent phosphate fertilizer, 2000 pounds of an 8 percent phosphate fertilizer and 2000 pounds of a 4 percent phosphate fertilizer plus 500 pounds of sulfur. The celery grown on these plots responded to the phosphate applications. The soil samples from the plots receiving no sulfur showed an average pH of 5.95 while those from the plots treated with sulfur averaged 5.60. The results of the soil tests are located by points on the chart in terms of pounds phosphorus per acre. The results of the tissue tests are plotted as percent phosphorus calculated to the dry weight basis. These points are connected by lines in order that a comparison may be made between soil tests and tissue tests by noting how well the lines parallel each other. For the three levels of phosphorus where the soil pH was not changed by sulfur treatment, the curves for the soil extractions made with carbonic acid and water parallel almost perfectly the tissue test curve. The acetic acid curve diverges slightly from the tissue test curve. The tissue tests indicate that the uptake of phosphorus by the celery plant at the 4P level and 5.60 pH is approximately the same as that at the 8P level and 5.95 pH. The relatively available phosphorus levels in the soil, as determined by carbonic acid and water extractions, very closely approximate the results of the tissue tests. However, the levels as determined by the 0.5*N* acetic acid do not. The relative values for available phosphorus as determined by acetic acid extractions do not appear to be reliable when used on soils where the pH values are not approximately uniform.

The great usefulness of tissue tests in evaluating soil tests has thus been quite definitely indicated. In view of this fact it has seemed advisable to make both tissue tests and soil tests on all plots being used for fertility studies. This practice has been followed during the past two years and has offered an opportunity for correlating soil tests and tissue tests with plant growth and yields. This offers two very practical applications of the data compiled for each crop studied. First, it furnishes a basis for making fertilizer recommendations for crops on the basis of soil tests made before fertilizing and planting the crop. Second, the tissue tests make it possible to offer suggestions as to corrective treatments to employ after the crop is planted. This is particularly true of crops fertilized in the row where there is no adequate method of soil sampling that will give representative material to work with.

Tissue tests in conjunction with soil tests not only provide a means of evaluating the soil tests but they have proved of inestimable value as an

aid to the interpretation of soil test and yield data from fertilizer plots. This is illustrated by an examination of the results of a potato fertility experiment conducted on raw sawgrass peat. Phosphate and potash were applied at four levels each making a total of sixteen treatments in five randomized blocks. Composite soil samples were taken from each block before the fertilizer was applied. Stem tissue tests for phosphorus and potassium were made on plant samples collected from each of the eighty plots. Analyses of variance showed highly significant differences between treatments for yields, tissue tests for phosphorus and tissue tests for potassium. Interactions between phosphate and potash were not significant. The potash data in terms of averages according to potash fertilizer treatment are shown graphically in Figure 4. Each point represents an average of twenty individual measurements. The yields are expressed in pounds per plot and the conducting tissue tests in percent potassium calculated

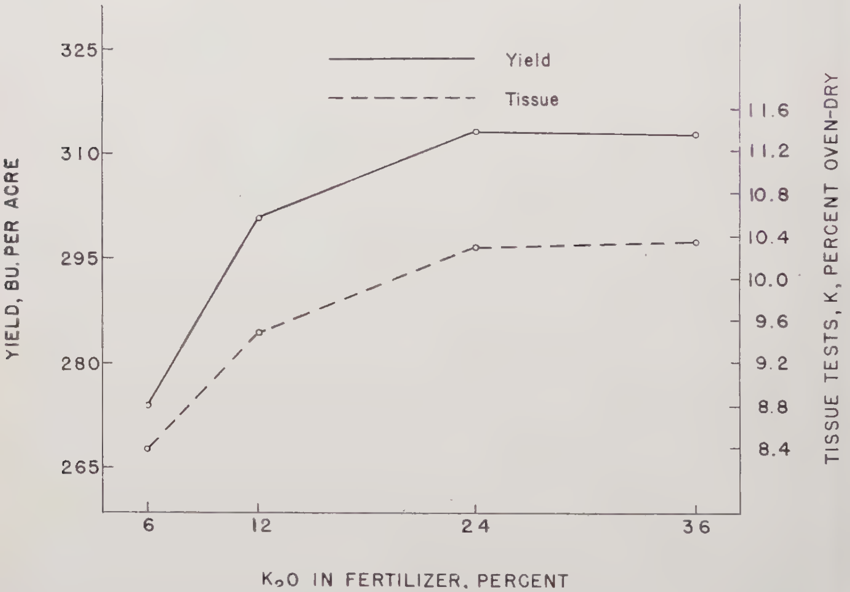

Figure 4.—Comparison of yields of potatoes with stem tissue tests of plant samples from plots receiving increasing increments of potash in the fertilizer.

on the oven dry basis. A statistical analysis of the yield data from the plots grouped according to potash treatment (upper curve) showed a highly significant response to a 12 percent over a 6 percent potash fertilizer. But the increase of the 24 percent over the 12 percent potash treatment indicated by the curve was not enough for significance. However, the tissue tests (lower curve) showed a highly significant increase of the 24 percent over the 12 percent potash treatment. The calculation of a correlation coefficient of yields versus tissue tests showed a positive value of high significance. Because of this high degree of correlation the stem tests seem to lend credence to the upward trend in yield due to a 24 per-

cent over a 12 percent potash fertilizer and thus allows a more liberal interpretation of the yield increase.

Rapid laboratory methods of soil analysis certainly have many useful possibilities in soils investigations. This is especially true in fertilizer studies for various crops on a particular soil type. When these tests are interpreted in the light of actual crop yields and are accompanied by tissue tests they present many interesting and valuable possibilities of practical application.

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SYMPOSIUM II: RELATION OF SOIL TYPE AND TREATMENT TO THE PRODUCTION OF FARM CROPS IN NORTH AND WEST FLORIDA

Newell Hall, Friday, February 15, 1946

2:00 P. M.

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THE RELATION OF SOIL TYPE AND FERTILIZER TREATMENT TO THE PRODUCTION OF COTTON IN NORTH AND WEST FLORIDA

Mr. R. L. Smith *

Since the coming of the Boll Weevil, the production of cotton in Florida has declined steadily and during the war years, the decline was rapid. The acreage for 1944 was fifty-six thousand acres and for 1945 twenty-five thousand acres—a decline of twenty-one thousand acres or forty-five percent in one year. This decline has been due to adverse conditions and to the development of other cash crops. The rapid decline from '44 to '45 was due to labor conditions and more abundant returns from peanuts, livestock and other crops.

Reasons for the production of cotton in north and west Florida are: need of a cash crop, it's a habit with some farmers, and, last but not least, soil types which are adapted to the production of cotton. Cotton grows well on the soils of this area and were it not for adverse weather conditions during the fruiting and harvesting stages, cotton would probably be the chief crop for north and west Florida.

The greater portion of the cotton acreage is planted on Red Bay, Ruston, Norfolk, Orangeburg and Arredondo types of soil with lesser acreage planted on the heavier types of soil such as—Magnolia, Marlboro, Tifton, Faceville and Greenville. Lighter soils generally produce an average yield, while the heavier, more fertile types produce an excellent yield in good years and very poor yields during bad years.

A cotton fertilizer formulae experiment was conducted on 22 farms during the years 1942 to 1944 inclusive. Various percentages of nitrogen, phosphoric acid and potash in a basic mixture were applied to cotton at the rates indicated in Table 1. Other treatments involving the use of split applications of nitrogen, addition of extra nitrogen as sidedressing, dolomitic limestone, and minor elements were included. The data indicate that cotton receiving a 2-8-4 fertilizer mixture produced 67 more pounds of seed cotton than that fertilized with an 0-8-4 mixture. In a like manner, applications of 4-8-4 and 6-8-4 mixtures, caused respective increases of 156 and 198 pounds per acre.

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TABLE 1.—THE EFFECT OF VARIOUS FERTILIZER TREATMENTS ON SEED COTTON YIELDS IN NORTHWEST FLORIDA—1942-44 INCLUSIVE.
(Mobile Units 1 & 2)

Fertilizer Treatment	Pounds of Seed Cotton Per Acre									
	Mobile Unit No. 2				Mobile Unit No. 1				Mobile Units No. 1 & 2	
	Average 2 Farms (1942)	Average 5 Farms (1943)	Average 4 Farms (1944)	Three Year Average	Average 4 Farms (1942)	Average 4 Farms (1943)	Average 3 Farms (1944)	Three Year Average	Average 22 Farms	Increase Over
										No K_2O
4-8-0	611	646	945	734	501	464	757	574	654	—
4-8-4	687	688	1090	822	645	613	917	725	774	120
4-8-8	701	686	1162	850	646	715	1043	801	826	172
4-8-12	699	750	1182	877	709	802	1163	891	884	230
										No P_2O_5
4-0-4	438	778	851	689	530	545	863	646	668	—
4-4-4	547	836	1102	828	584	626	927	712	770	102
4-8-4	687	872	1184	914	645	658	970	758	836	168
4-12-4	692	804	1197	898	685	711	963	786	842	174
										No N
0-8-4	561	707	894	721	465	499	947	637	679	
2-8-4	597	784	1024	802	532	544	993	690	746	67
4-8-4	687	856	1143	895	645	629	1047	774	835	156
6-8-4	719	852	1152	908	706	764	1070	846	877	198
										No 4-8-4
2-8-4 (a)	—	937	1151	1044	—	781	1150	966	1005	157
4-8-4	687	805	1204	899	645	633	1110	796	848	—
4-8-4 Soda (b)	—	—	1312	1312	—	—	1153	1153	1233	385
4-8-4 + D (c)	560	907	1166	878	624	781	1057	821	850	2
4-8-4 + ME (d)	583	832	1209	875	648	790	1053	830	853	5

(a)—Half of nitrogen applied as sidedressing
(b)—Received 150 pounds nitrate of soda as sidedressing
(c)—250 Dolomitic Limestone
(d)—Minor Elements

Plots: Two 1/20 acre plots at each location
Soils: Arredondo, Norfolk, Ruston, Red Bay and Magnolia

Fertilizer: Mobile Unit No. 1—1942 and 1943, 300 lbs. per acre of indicated formulae, 1944—500 lbs. of indicated formulae.
Mobile Unit No. 2—1942, 400 lbs. of indicated formulae, 1943—300 lbs. of indicated formulae, 1944—400 lbs. of indicated formulae.
Sidedressing applied as indicated in table above.

When one-half of the nitrogen was applied with phosphorus and potash before planting and the remaining half applied as sidedressing, the average yield of cotton over a two-year period on 16 farms was increased 67 pounds per acre. In a one-year average on 7 farms, the addition of 100 pounds of nitrate of soda, as sidedressing to cotton receiving 4-8-4 before planting resulted in an increase of 75 pounds of seed cotton per acre.

In the part of the experiment regarding the use of phosphoric acid, the following formulae were used: 4-0-4, 4-4-4, 4-8-4, and 4-12-4. The increase in yield over the 4-0-4 (no phosphorus) was respectively, 102, 168, and 174 pounds of seed cotton per acre. The increase in yield over that of the preceding rate was respectively, 102, 66 and 6 pounds per acre. This would indicate that 8-10 percent of phosphoric acid would be sufficient for cotton in this area. The response to phosphorus was greater in the area of Mobile Unit No. 2 than in that of Mobile Unit No. 1.

Cotton receiving applications of 4-8-0, 4-8-4, 4-8-8, and 4-8-12 fertilizer, averaged respectively, 654, 774, 826 and 884 pounds of seed cotton per acre. Increases for successive increments over preceding rates of potash are: 120, 52, and 58 pounds per acre. The response of cotton to potash in the area of Mobile Unit No. 1 was considerably higher than that in Mobile Unit No. 2.

Dolomitic limestone mixed with the fertilizer and applied before planting, had very little effect on the yield of cotton.

A mixture of zinc sulphate, copper sulphate, magnesium sulphate, manganese sulphate, and borax applied with the fertilizer before planting resulted in a slight increase in the yield of seed cotton, but was not considered significant.

The data shown in Table 1 was rearranged according to soil type in Table 2. The response to nitrogen on the various types of soil was: Ruston and Magnolia excellent, Red Bay and Norfolk, good, Arredondo, fair, and Orangeburg, low. The addition of phosphoric acid caused a good increase in the yield of cotton on all of the soil types, with the greatest increment on the Ruston and Magnolia types.

In regard to potash, the data indicate that 60 pounds of K_2O was not sufficient to meet the needs of cotton on Ruston, Orangeburg and Norfolk types of soil. A good response was also obtained on Arredondo and Magnolia types, but a very poor increase resulted on the Red Bay types. Cotton on Ruston type soil gave an excellent response to all of the three major plant food elements.

Having accumulated considerable data from the cotton fertilizer experiment, it was decided that the experiment would only be conducted on land where peanuts had been dug the previous year. Experiments were conducted on six farms in 1945 by Mobile Units 2 and 3. These areas produce large quantities of peanuts year in and year out. In the area of Mobile Unit 2, the response to nitrogen and potash was good, and to phosphoric acid it was excellent. In the area of Mobile Unit No. 3, a high response to potash and a low response to nitrogen and phosphoric acid was obtained.

TABLE 2.—EFFECT OF FERTILIZER TREATMENT ON COTTON YIELD WITH RESPECT TO SEVERAL SOIL TYPES.

Treatment	Yield in Pounds of Seed Cotton per Acre						Increase in Yield of Seed Cotton in Pounds per Acre					
	Red Bay 6 Farms * 1—5	Ruston 5 Farms * 3—2	Magnolia 3 Farms * 0—3	Orange-burg 2 Farms * 2—0	Norfolk 3 Farms * 2—1	Arre-dondo 3 Farms * 3—0	Red Bay 6 Farms	Ruston 5 Farms	Magnolia 3 Farms	Orange-burg 2 Farms	Norfolk 3 Farms	Arre-dondo 3 Farms
0-8-4	847	679	733	714	549	393	—	—	—	—	—	—
2-8-4	967	713	833	768	607	423	120	34	100	54	58	30
4-8-4	1049	833	954	770	748	481	202	154	221	56	199	88
6-8-4	1057	943	1001	785	765	555	210	264	268	71	216	162
4-0-4	879	720	707	560	575	407	—	—	—	—	—	—
4-4-4	936	921	825	633	647	444	57	201	118	73	72	37
4-8-4	998	958	967	662	772	454	119	238	260	102	197	47
4-12-4	981	990	937	713	663	532	102	270	230	153	88	125
4-8-0	911	669	772	432	468	317	—	—	—	—	—	—
4-8-4	927	842	911	592	619	467	16	173	139	160	151	150
4-8-8	908	918	864	802	702	567	-3	249	92	370	234	250
4-8-12	961	1016	733	827	762	548	50	347	—39	395	294	231

* First figure refers to Mobile Unit No. 1—second figure to Mobile Unit No. 2.

Plots: Two 1/20 acre plots of each treatment at each location.

Soil Types: As indicated in table.

Fertilizer: Mobile Unit No. 1—1942 and 1943, 300 lbs. per acre of indicated formulae, 1944—500 lbs. of indicated formulae.
Mobile Unit No. 2—1942, 400 lbs. of indicated formulae, 1943—300 lbs. of indicated formulae, 1944—400 lbs. of indicated formulae.
Sidedressing applied as indicated in table above.

TABLE 3.—Effect of Various Fertilizer Treatments on Yield of Seed Cotton Following Dug Peanuts.
(Mobile Units 2 & 3)

Fertilizer Treatment	Yield in Pounds of Seed Cotton per Acre									
	Mobile Unit No. 2				Mobile Unit No. 3				Units No. 2 & No. 3	
	Farm No. 1 Magnolia f.s.l.	Farm No. 2 Norfolk f.s.l.	Farm No. 3 Red Bay f.s.l.	Average Of Three Farms	Farm No. 1 Marlboro f.s.l.	Farm No. 2 Norfolk f.s.l.	Farm No. 3 Ruston f.s.l.	Average Of Three Farms	Average of Both Units—Six Farms	Average Increase Over
0-8-4	985	1125	1808	1073	783	305	727	605	839	No N
2-8-4	1319	1175	1156	1217	961	364	751	692	955	116
4-8-4	1647	1076	1211	1311	772	527	806	702	1007	168
6-8-4	1086	1167	1237	1163	735	591	858	728	946	107
4-0-4	993	823	901	906	756	581	638	658	782	No Phos.
4-4-4	1339	1119	978	1049	587	573	829	663	856	74
4-8-4	1146	1169	1059	1125	606	713	1038	786	956	174
4-12-4	1130	1445	1202	1259	689	505	996	730	995	213
4-8-0	1109	591	1014	905	513	320	662	498	702	No K_2O
4-8-4	1422	682	1062	1055	655	535	930	707	881	179
4-8-8	1588	733	1103	1141	954	487	1080	840	991	289
4-8-12	1538	640	1208	1129	1000	564	1129	898	1014	312
4-8-4	1287	989	1012	1096	860	467	997	775	936	4-8-4
4-8-4 — 100 lbs. nitr. soda	1222	1277	1090	1196	959	600	1089	883	1040	104
4-8-4 — 100 lbs. ammon. nitr.	1341	1243	1122	1202						

Plots: Two 1/20 acre plots of each treatment at each location.
Fertilizer: 500 lbs. per acre of indicated formulae plus sidedressing where indicated.
Soil Types: As indicated above.

TABLE 4.—Effect of Various Fertilizer Treatments on Yield of Seed Cotton, Following Dug Peanuts.
(Mobile Units 2 & 3)

Fertilizer Treatment	No. 2		No. 3		No. 2 and No. 3	
	Average Three Farms	Average Increase Over	Average Three Farms	Average Increase Over	Average Both Units 6 Farms	Average Increase Over
0-8-4	1073	No N	605	No N	839	No N
2-8-4	1217	144	692	87	955	116
4-8-4	1311	238	702	97	1007	168
6-8-4	1163	90	728	123	946	107
4-0-4	906	No Phos.	658	No Phos.	782	No Phos.
4-4-4	1049	143	663	5	856	74
4-8-4	1125	219	786	128	956	174
4-12-4	1259	353	730	72	995	213
4-8-0	905	No K_2O	498	No K_2O	702	No K_2O
4-8-4	1055	150	707	209	881	179
4-8-8	1141	236	840	342	991	289
4-8-12	1129	224	898	400	1014	312
4-8-4	1096	4-8-4	775	4-8-4	936	4-8-4
4-8-4 + 100 lbs. nitrate s.	1196	100	883	108	1040	104
4-8-4 + 100 lbs. ammon. ni.	1202	106				

Soils: Magnolia, Norfolk, Ruston, Marlboro and Red Bay.

TABLE 5.—Effect of Fertilizer Treatment on Cotton Yield with Respect to Soil Type.

Treatment	Increase in Yield of Seed Cotton in Pounds per Acre					
	Red Bay 6 Farms	Ruston 5 Farms	Magnolia 3 Farms	Orange-burg 2 Farms	Norfolk 3 Farms	Arre-dondo 3 Farms
0-8-4	—	—	—	—	—	—
2-8-4	120	34	100	54	58	30
4-8-4	202	154	221	56	199	88
6-8-4	210	264	268	71	216	162
4-0-4	—	—	—	—	—	—
4-4-4	57	201	118	73	72	37
4-8-4	119	238	260	102	197	47
4-12-4	102	270	230	153	88	125
4-8-0	—	—	—	—	—	—
4-8-4	16	173	139	160	151	150
4-8-8	—3	249	92	370	234	250
4-8-12	50	347	—39	395	294	231
4-8-4 lime	—	—	—	—	—	—
4-8-4 M E	—	—	—	—	—	—

TABLE 6. Effect of Various Treatments on Seed Cotton Yields in Northwest Florida—1942-44 Inclusive.
(Mobile Units 1 & 2)

Fertilizer Treatment	Pounds of Seed Cotton per Acre				
	No. 2 Three Year Average	No. 1 Three Year Average	Average 22 Farms	Increase Over	Percent Increase
				No K_2O	
4-8-0	734	574	654	—	—
4-8-4	822	725	774	120	18.3
4-8-8	850	801	826	172	26.3
4-8-12	877	891	884	230	35.2
				No P_2O_5	
4-0-4	689	646	668	—	—
4-4-4	828	712	770	102	15.3
4-8-4	914	758	836	168	25.1
4-12-4	898	786	842	174	26.0
				No N	
0-8-4	721	637	679	—	—
2-8-4	802	690	746	67	9.9
4-8-4	895	774	835	156	23.0
6-8-4	908	846	877	198	29.2
				No 4-8-4	
2-8-4	1044	966	1005	157	7.7
4-8-4	899	796	848	—	—
4-8-4 Soda	1312	1153	1233	385	8.0
4-8-4 + D	878	821	850	2	
4-8-4 + ME	875	830	853	5	

Soils: Arredondo, Norfolk, Ruston, Red Bay and Magnolia.

THE RELATION OF SOIL TYPE AND FERTILIZER TREATMENT TO THE PRODUCTION OF PEANUTS IN NORTH AND WEST FLORIDA

MR. R. W. WALLACE *

Two factors are involved in determining the nutritional requirement of peanuts. First, there is the fertilization of the peanut crop itself without consideration of the other crops in the rotation, and second, there is the necessity for maintaining the general level of fertility of the soil when peanuts are grown in rotation with other crops. Peanuts have long been considered a soil depleting crop, therefore its commercial value may be discounted considerably. The peanut plant is a legume and is generally included in the list of plants called soil building. However, the general practice of digging the peanuts and removing the nuts, roots and vines followed by turning hogs into the field to glean any remaining nuts and vegetable matter is contrary to all accepted practices of maintaining soil fertility. The effect of hogging-off peanuts is quite different from digging the nuts. Many practical growers have found from experience that hogging-off peanuts is a good soil building practice.

It has been calculated that 2000 pounds of nuts and 6000 pounds of hay remove from the soil 85 pounds of nitrogen, 15 pounds of phosphoric acid and 50 pounds of potash. It has also been found that a very large percentage of the nutrients is removed in the hay. Collins and Morris [1] present figures which show that one ton of peanut hay removes from the soil 39.4 pounds of nitrogen, 27.5 pounds of calcium, 5.3 pounds of phosphoric acid, 41.1 pounds of potash and 12.6 pounds of magnesium.

FERTILIZER PLACEMENT

The method of applying fertilizer is an important factor to be considered in the fertilization of peanuts. The fertilizer should be applied in such a manner that it will not seriously affect the germination of the seed and development of the seedling plant. Indications are that the peanut kernels are more sensitive to fertilizer salts than many other field crops. Seed injury from fertilizer may result more frequently on light sandy soils than on the heavier types, and is more severe in times of least rainfall. With many other crops, the problem of fertilizer placement has been worked out through years of research, but little or no data has been published along this line with peanuts.

EXPERIMENTAL WORK WITH PEANUTS

With the above facts in mind the Mobile Units of the North Florida Experiment Station conducted fertilizer experiments on six soil types in

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* Data presented in this paper were obtained by R. W. Wallace, R. L. Smith and R. W. Lipscomb of Mobile Units 1, 2 and 3 of the North Florida Experiment Station.

[1] Collins, E. H. and Morris, H. D. on Soil Fertility Studies With Peanuts. N. C. Agricultural Experiment Station. Bul. 330. 1942.

Northwest Florida. Soil types on which the tests were conducted include Norfolk, Ruston, Arredondo, Red Bay, Orangeburg, and Dunbar fine sandy loams.

RESPONSE TO POTASH

Of all the fertilizer problems with peanuts, none has been so difficult to understand as that involving potash. The peanut plant apparently can take up potash that is not available to other plants. It is well known that a harvested crop of peanuts removes large amounts of potash from the soil. Light applications of potash in many cases increased the yield of nuts as much as heavy applications. The response to potash was less pronounced on Red Bay than on the other soil types on which the experiments were conducted. The highest response was obtained on the Norfolk soil series.

Crops following harvested peanuts often show symptoms of a potash deficiency. Probably the best method of replacing part of the potash removed by the peanuts, is by increasing the rate of application to crops that follow peanuts in the rotation.

RESPONSE TO GYPSUM AND LIMESTONE

From data presented in Table 1 it is very evident that calcium plays an important role in the production of peanuts. Gypsum was applied on the foliage at the time of first blooms at the rate of 200 pounds per acre and resulted in a 10.61 percent increase in yield. Dolomitic limestone was applied in the drill at planting at the rate of 500 pounds per acre and resulted in a 3.66 percent increase in yield. The response was greater from both gypsum and lime on the Arredondo, Norfolk and Orangeburg soils than on Ruston, Red Bay or Dunbar.

RESPONSE TO NITROGEN

There was little to no response from nitrogen applied at the rates of 6 and 12 pounds per acre. Each rate resulted in an increased yield of only approximately 5 percent over the plot which received no nitrogen. The least response was on the Red Bay and Dunbar soils and the greater increases were on the Orangeburg and Arredondo soils.

RESPONSE TO PHOSPHORUS

The response to phosphorus was more pronounced than from nitrogen. Plots which received only superphosphate gave an increased yield of 14.54 percent over plots which did not receive any fertilizer. Likewise, plots which received only basic slag gave an increased yield of 18.92 percent over the non-fertilized plots. However, when the phosphoric acid was increased to 48 pounds the increase over the basic treatment of 30 pounds was only 3.96 percent. The response was greater on the Arrendondo and less on Red Bay than on the other soil types. Again the crop rotation should be considered in applying phosphorus to peanuts.

TABLE 1.—PERCENT INCREASE OF PEANUTS FROM VARIOUS FERTILIZER BY SOIL TYPES. *
North Florida Experiment Station—Mobile Units, 1942-1944 Inclusive

Fertilizer Treatments	SOIL TYPES						AVERAGE
	Ruston f. s. l. 9 Farms	Norfolk f. s. l. 7 Farms	Red Bay f. s. l. 6 Farms	Orangeburg f. s. l. 2 Farms	Arredondo f. s. l. 1 Farm	Dunbar f. s. l. 1 Farm	26 farms
0-0-0	0	0	0	0	0	0	0
0-10-4	15.45	34.07	4.40	13.24	27.03	14.28	18.14
2-10-4 (check)	21.30	32.03	10.31	39.70	40.54	9.09	23.34
4-10-4	21.98	31.69	6.42	42.94	40.54	6.49	22.73
0-10-0 Superphosphate	12.64	23.90	0.88	20.59	28.38	22.08	14.54
0-10-0 Basic Slag	17.31	19.15	12.83	30.29	55.40	9.09	18.92
2-10-4 Basic Slag	25.83	14.92			39.19	32.47	22.70
2-10-8	20.77	35.42	8.18	21.47	22.97	31.17	22.35
2-10-0 8% K as S. D.	29.69	33.05			56.76	19.48	31.93
2-16-4	23.96	42.03	14.34	14.70	68.92	15.58	27.30
2-10-4 + 200 lb. Gypsum	32.89	51.02	15.97	34.70	43.24	20.78	33.94
2-10-4 + 500 lb. Limestone	19.30	35.42	13.71	52.35	62.16	29.87	26.95
2-10-4 + M. Elements **	23.70	28.64		78.82	48.65	24.68	32.24
2-10-4 + 60 lb. Cu. Sul.	58.59	62.88	28.55	98.53	125.68	58.44	58.46
2-10-4 + 60 lb. Sul. Dust	43.28	69.49	22.64	77.94	90.54	24.02	49.32
AVERAGE	26.19	36.69	12.57	43.77	53.57	22.68	28.78

* The increases of peanuts from the general sulfur dusting experiments have been omitted from these averages, only the plots carrying copper-sulfur and sulfur have been averaged, all other averages are from non-dusted plots.

** 10 lb. Copper sulfate, 10 lb. magnesium sulfate, 5 lb. zinc sulfate and 5 lb. Borax.

Fertilizer: 300 pounds per acre of indicated formulae.

Plot size: 1/20 and 1/10 acre.

RESPONSE TO MINOR ELEMENTS

Under the conditions of these experiments the addition of copper, zinc, magnesium and boron increased the yield of nuts 8.90 percent over the basic fertilizer treatment, however, this small increase is probably not significant.

EFFECT OF SULPHUR DUST ON THE YIELD OF PEANUTS

Experiments conducted on 49 farms have given profitable yield increases from dusting peanuts with sulphur dust to control leaf spot. Twelve of the tests were in conjunction with various fertilizer treatments, the results of which are presented in Table 2. It will be noted that the increased yield ranged from 15.89 percent on the no-fertilizer plots to 33.49 percent on the plot which received 300 pounds per acre of a 4-10-4 mixture. The average increased yield from all dusted plots over the non-dusted plots was 23.41 percent. Experiments comparing sulphur dust, copper-sulphur dust (10-90) and no dust were conducted for one year only on 20 farms. The results are presented in Table 3. The average percentage increase of sulphur and copper-sulphur over no dust was 22.9 and 27.1

TABLE 2.—RESULTS OF PEANUT FERTILIZER EXPERIMENTS IN NORTHWEST FLORIDA—1944.
Dusted vs Undusted

Yield Expressed in Pounds of Nuts per Acre

Fertilizer Treatment	Average Yield 12 Farms		Increase Over Undusted	
	Dusted	Undusted	Pounds	Percent
0-0-0	700	604	96	15.89
0-10-4	866	695	171	24.64
2-10-4	842	708	134	18.93
4-10-4	897	672	225	33.48
0-10-0 Superphosphate	811	654	157	24.01
0-10-0 Basic Slag	854	698	156	22.35
2-10-4 Basic Slag	891	707	184	26.03
2-10-8	847	710	137	19.26
2-10-8 + 8% K as S. D.	866	732	134	18.31
2-16-4	899	725	174	24.00
2-10-4 + 200 lbs. Gypsum	949	767	182	23.73
2-10-4 + 500 lbs. Dol. Limestone	923	707	216	30.53
2-10-4 + Minor Elements *	841	706	135	19.12
2-10-4 + 60 lbs. Cu. Sulfur Dust	913	—	205	28.95
2-10-4 + 2 lbs. Na MO4	788	656	132	20.12
2-10-4 + 2 lbs. H MO4	880	703	177	25.18

* 10 lbs. copper sulfate, 10 lbs. magnesium sulfate. 5 lbs. zinc sulfate and 5 lbs. Borax.

Fertilizer: 300 pounds per acre of the indicated formula.

Soil Type: Ruston f. s. l.—4 farms.
Norfolk f. s. l.—3 farms.
Red Bay f. s. l.—2 farms.
Orangeburg f. s. l.—1 farm.
Arredondo f. s. l.—1 farm.
Dunbar f. s. l.—1 farm.

TABLE 3.—Results of Peanut Dusting Experiment—1944.

County	Dusting Dates			Variety	Acreage Dustsed	Yield in Pounds per Acre			Increase Over No Dust			
						Sulfur Dust	Copper-Sulfur Dust	No Dust	Sulfur		Copper-Sulfur	
									Pounds	Percent	Pounds	Percent
Jefferson	6/26	7/10	7/21	Spanish	2.00	1610	1503	1317	293	22.2	186	14.1
Jefferson	6/26	7/10	7/21	Runner	4.80	1021	—	854	167	19.6	—	—
Jefferson	6/27	7/11	7/24	Spanish	1.60	711	672	622	89	14.3	50	8.0
Jefferson	7/6	7/18	8/1	Spanish	1.00	984	1132	658	326	49.5	474	72.0
Jefferson	7/6	7/18	8/1	Runner	1.00	611	718	410	201	49.0	308	75.1
Leon	6/30	7/12	7/28	Spanish	1.00	1384	1453	940	444	47.2	513	54.6
Leon	6/29	7/14	7/28	Runner	.80	973	—	664	309	46.5	—	—
Jefferson	6/29	7/14	7/27	Runner	.80	955	—	801	154	19.2	—	—
Madison	6/20	7/3	7/18	Runner	.80	639	—	553	86	15.6	—	—
Madison	6/20	7/3	7/17	Runner	.80	743	—	597	146	24.5	—	—
Jackson	6/21	7/1	7/13	Spanish	.70	491	437	443	48	10.8	—6	—1.4
Jackson	6/22	7/5	7/14	Runner	.30	788	1022	852	—64	—7.5	170	19.9
Jackson	6/20	6/30	7/11	Spanish	.35	1337	—	1311	26	2	—	—
Jackson	6/23	7/7	7/14	Spanish	.45	1370	—	1149	221	19.2	—	—
Jackson	6/23	7/7	7/14	Runner	.75	355	—	361	—6	—1.7	—	—
Jackson	6/23	7/7	7/17	Runner	.75	1589	—	1038	551	53.1	—	—
Jackson	6/23	7/7	7/14	Spanish	1.00	1250	—	1165	85	7.3	—	—
Jackson	6/23	7/7	7/14	Spanish	1.20	592	—	345	247	71.6	—	—
Washington	6/27	7/10	7/17	Runner	.35	1172	—	981	191	19.5	—	—
Calhoun	6/29	7/10	7/18	Spanish	.98	999	—	866	133	15.4	—	—
AVERAGE					1.07	979	913	796	183	22.9	195	27.1

Sulfur dust and copper-sulfur dust applied at the rate of approximately 60 pounds per acre.

percent respectively. The yields do not take into consideration the amount of nuts left in the soil. Bledsoe, Harris and Clark [2] published data showing the amount of nuts left in the soil is of importance in any study involving yield data. This may reflect on the total yield of peanuts due to sulphur treatments.

CONCLUSIONS

From data obtained on several soil types in Northwest Florida it may be concluded that on soils of average fertility in a rotation with other crops which have received little or no fertilizer, an application of 300 pounds per acre of a 2-10-4 fertilizer will furnish sufficient nitrogen, phosphorus and potash for peanuts. With the addition of 200 to 400 pounds of gypsum on soils with a low calcium level or 300 to 500 pounds of dolomitic limestone on soils with a high calcium level, one could expect 3 to 10 percent increase in yield. Dusting with sulphur may further increase the yield of nuts 20 to 30 percent.

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[2] Bledsoe, R. W., Harris, H. C. and Clark, Fred, On the importance of peanuts left in the soil in the interpretation of increases in yield due to sulphur treatment. Jour. Amer. Soc. Agron. V37, No. 9, 1945.

THE RELATION OF SOIL TYPE AND TREATMENT TO THE PRODUCTION OF CORN IN NORTH AND WEST FLORIDA

Mr. J. D. Warner *

Quite extensive reference was made in the course of Mr. Warner's discussion to a considerable amount of fertility work that has been done in North and West Florida with corn in the past, the results of which largely are unpublished. The importance of the unusual responses obtained to such trace elements as zinc in the curing of the so-called "white bud" in corn on certain soils also was cited, especially in relation to the results of the fertility work that had gone before. Inter-relationships of fertility work with soil type were touched upon wherever significant information was available in this connection. Unfortunately, no formal manuscript to cover this phase of the roundtable discussion was provided. Ed.

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THE RELATION OF SOIL TYPE AND FERTILIZER TREATMENT TO THE PRODUCTION OF PASTURES IN NORTH AND WEST FLORIDA

Dr. G. B. Killinger *

Pastures are now being recognized as a profitable part of Florida agriculture. For many years Florida farmers and cattlemen have paid little or no attention to improving pastures. The reasoning for this lack of interest was most probably due to (1) plenty of cut-over timberland available, (2) many acres of native vegetation not under fence and open to public grazing, (3) low price of most Florida cut-over lands.

In the early- to mid-30s the Government started paying subsidies for improving pastures. Prior to this time all lands not in other crops or fenced were considered possible pasture land and much of it was grazed by mixed lots and numbers of range cattle. Subsidies for improving pastures stimulated cattlemen to fence, chop and destroy native vegetation, lime, fertilize and seed many acres for pasture purposes. At this time over a million acres have been improved. Some of this land has been chopped only, destroying native vegetation, chiefly wire grass and palmetto, and seeded; some has had a complete set of treatments qualifying for maximum payments from the Federal Government.

The pasture program in Florida has been further stimulated by the finding of successful methods for growing White Dutch and other clovers and lespedeza. New rust-resistant oat strains developed at the North Florida Experiment Station and main Station at Gainesville have given great stimulus to the cattle industry in central and north Florida. Now on most tillable lands in this section of Florida green oat grazing can be had from December through April, or until spring and summer grasses are ready. New grasses, namely: Pangola, Pensacola Bahia, and Coastal Bermuda, have given cattlemen a choice of grasses other than carpet grass and common Bahia which have been most commonly seeded in past years. All of these grasses are far superior to wire grass and all respond to fertilization.

Soil type determines in many cases the grass best suited to a certain pasture and is always a determining factor when White Dutch clover is to be seeded. Moisture, temperature and fertility are highly important in pasture farming.

In total acreage the flat woods, or commonly called pine woods, land predominates for potential quality pastures. The Leon soils occupy over half of the flat woods area and therefore become the one soil series comprising the greatest pasture acreage. Leon soils are quite varied in their ability to support certain of the pasture plants. White Dutch clover grows well on some of the low phases, particularly if they are well fertilized with organic matter. In general, it can be said that carpet grass will grow on most Leon soils, Bahia on some, particularly the well-drained areas,

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Bermuda and Pangola on the higher phases and lespedeza and clover on the more moist phases. Carpet and Bahia grass can be grown without fertilization: however, a complete fertilizer and, in some sections of the State, minor elements speed up the sodding or grassing over of a pasture. Lime is not essential, but when applied to a Leon soil in which the pH range is usually from 4 to 5, the resulting calcium content of herbage is greatly increased. When legumes are to be grown on this soil, from 1 to 2 tons of lime is practically a necessity with high calcic lime proving superior to dolomitic in most instances. A fertilizer carrying about 14 percent phosphoric acid and 10 percent potash at the rate of 500 to 600 pounds per acre has proven best. The phosphate and potash fertilizer must be applied annually for good clover growth. In addition to Leon; Portsmouth, Bladen, Plummer, Bayboro, Alachua and Fellowship soils have produced satisfactory clover in combination with carpet grass. Fertility requirements of these soils remain about the same for the growing of clover. It generally can be said that both clover and lespedeza do best when grown on the heavier textured, dark, moist soils. Both legumes respond to phosphate, potash, and lime; however, lespedeza will grow at a lower fertility level and is not demanding of lime. Carpet, Pangola, and Bermuda grass grow best on the moist (but well-drained), heavy textured black soils but will do well on the higher more droughty sands. Common Bahia is well suited to the more droughty soils, while Pensacola Bahia appears to be adapted to both moist and dry soils.

As might be expected all of the improved grasses are highest in mineral constituents when properly fertilized.

Duplicate 2.5 acre pastures were fenced on the Station Farm in 1940 on Plummer and Portsmouth soils, and fertilized for carpet grass, carpet grass and clover, and carpet grass and lespedeza. The acre yield of dry herbage and gain in pounds of beef per acre are given in Table 1. These results show the benefits that can be expected from fertilizing carpet grass

TABLE 1.—Average Annual Yield, Dry Herbage and Beef per Acre.

Herbage	* Treatment	4 Year Average, 1942-45 Pounds Per Acre	
		Dry Herbage	Beef
Carpet Grass	No Fertilizer	2,373	76
Carpet Grass	Fertilized	4,321	150
Carpet Grass-Clover	Fertilized	9,009	583
Carpet Grass-Lespedeza	Fertilized	4,074	225

* Fertilized carpet grass received 1 ton calcic lime and 400 lbs. of an 8-8-5 fertilizer first year, 400 lbs. of 8-8-5 second year, and 500 lbs. per acre of a 6-6-6 the third, fourth and fifth years.

Fertilized carpet grass and clover received 1½ tons of calcic lime and 600 lbs. of 0-16-8 the first year, 300 lbs. of 0-16-8 the second, and 400 lbs. of 0-10-10 the third, fourth and fifth years.

Fertilized carpet grass and lespedeza received 1 ton calcic lime and 350 lbs. of 0-16-8 the first year with 300 lbs. of 0-10-10 annually thereafter.

1st year—Fertilized Carpet Grass average gain—118 pounds beef.

1st year—Fertilized Carpet Grass and Clover average gain—300 lbs. beef.

Figure 1.—Steers grazing clover in January. Note early season growth as compared to dead carpet grass in right background.

Figure 2.—Steers grazing same clover field as Figure 1 in May. Note full bloom and abundance of forage.

and the value of growing a legume in combination with the grass. Figures 1, 2 and 3 show growth of fertilized grass and clover.

Table 2 gives the carpet grass response on Bladen fine sand, Leon fine sand and Plummer fine sand with and without fertilizer. The carpet grass response is given both in yield and composition of herbage.

TABLE 2.—Carpet Grass Response to Fertilizer on Several Soil Types.

Soil Type	Treatment Pounds Per Acre				Percentage Composition of Grass on Oven-dry, Sand-free Basis					Yield Index
	N	P_2O_5	K_2O	Lime	N	P	K	Ca	Mg	
Bladen f. s.	0	0	0	0	1.869	0.134	0.640	0.355	0.161	10
	72	144	100	2000	1.945	0.169	0.794	0.544	0.257	78
Leon f. s.	0	0	0	0	1 872	0.183	1.399	0.481	0.159	18
	72	144	100	2000	1.886	0.260	1.325	0.689	0.130	100
Plummer f. s.	0	0	0	0	1.846	0.198	1 382	0.502	0.156	13
	72	144	100	2000	1.837	0.208	1.556	0.624	0.100	48

The greatly increased yield, due to fertilizer and lime treatment, with an increase in phosphorus and calcium are highly significant. In most instances applications of potash markedly increased the potassium content of Carpet Grass herbage

Figure 3.—Steers on fertilized carpet grass in May. Note lack of vegetation as compared to clover field.

RELATED FACTORS IN TOBACCO PRODUCTION

Mr. Fred Clark *

The growing of tobacco, a crop that requires special handling and care for maximum yield and quality, has become localized because of its soils and climate requirements. For example, Bright tobacco is produced in Virginia, North and South Carolina, Georgia, Florida and Alabama. In this geographical area there are two tobacco belts, known as the "old" and "new". The main difference in these two belts is the soil. Soils in the "old belt" are loams and sandy loams mostly in the Piedmont, and are derived from underlying granite. The subsoils in this area are usually heavy clays. The "new belt" soils, which include Florida, are more sandy, gravelly soils of Marine origin and are in the Coastal Plain section. Thus, the same type tobacco is grown on different soils, and many of the same varieties are grown in both areas. The "old belt" produces a heavier-bodied, darker tobacco than the "new belt". Fertilization, cultural and curing methods may vary from one area to another, or within the same area, making for further specialization.

Bright tobacco, in which we are primarily interested, is commonly called flue-cured, because of the method used for curing the tobacco. The physical properties of the soil seem to be more important than the chemical, because it is the very light sandy soils that are best adapted to Bright tobacco, i.e., fluecured tobacco. It is easier to adjust a fertilizer program in the light soils for tobacco since it is one of the highly fertilized crops, and the quality of the crop as well as the yield is dependent upon available plant food.

Nitrogen and certain other materials must be controlled so that these elements are depleted as tobacco nears maturity if good yields and quality leaf are to be harvested and cured. Quality has not influenced the price in the past two or three crop years, but growers should not lose sight of its importance.

Soil types on which fluecured tobacco is grown in Florida are: Norfolk fine sand; Blanton fine sand; Arredondo fine sand and loamy fine sand; Gainesville loamy fine sand; Archer fine sand, loamy fine sand, and fine sandy loam; Hernando fine sand, loamy fine sand, and fine sandy loam; Newberry fine sand; Ruston loamy fine sand; Norfolk loamy fine sand; Marlboro; Tifton; and Orangeburg.

Recent experiments conducted on a Norfolk fine sandy soil at the Florida Agricultural Experiment Station have given some interesting and worthwhile results. The experimental work did not vary to any extent over regular practices except in formulation of treatment. The following is a brief summary of the tobacco rotation practices for these experiments: The first year tobacco was planted on an old abandoned field which had been cleared of second growth, oaks, pine and sparse wire grass ground cover. The tobacco was followed by oats in the fall which were harvested the following spring, and cattail millet and peas were planted for a sum-

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mer cover crop. The following fall oats were again planted and harvested the next spring, and the land was allowed to grow to native weeds and grass for summer cover. Native weeds and grass were always grown on the soil preceding a planting of tobacco. The weed and grass cover was plowed and disked thoroughly before planting.

With this system of soil and crop management, experiments were initiated with:

1. 39 formulae tests.
2. Sources and combination of sources of nitrogen.
3. Rates and numbers of plants per acre.
4. Acid, basic, and neutral mix fertilizers.
5. Minor elements.
6. Varieties.

Formulae tests were carried on in series:

1. Nitrogen.
2. Phosphorus.
3. Potassium.
4. Calcium.
5. Magnesium.
6. Sulfur.
7. Chlorine.
8. Boron.

Rates of each of these elements were used at levels lower and higher than normal applications. A standard mix or check formula was used in all series and these treatments were in triplicate and duplicate plots. The check treatment consisted of 30 pounds nitrogen, 80 pounds phosphoric acid, (P_2O_5), 60 pounds potash (K_2O), 80 pounds calcium oxide (CaO), 20 pounds magnesium oxide (MgO), 89 pounds sulfur trioxide (SO_3), 20 pounds chlorine (cl), and 5 pounds boron per 100 pounds of fertilizer per acre. All other elements were standard with only the element under study being varied from the check plots.

Rates of Nitrogen. Nitrogen applications ranged from 0 to 45 pounds per acre, with a 30 pound rate of nitrogen producing the highest yield. Most sandy soils are low in nitrogen and usually little if any green manure crop has been grown preceding the tobacco crop. Treatments in which nitrogen was withheld produced the poorest tobacco growth. Heavy rates of nitrogen did not delay tobacco growth as measured by flowering. Heavy rates produced a rough, dark green leaf and these did not ripen as readily as the lower rates of nitrogen.

Rates of Phosphoric Acid. From 5 to 192 pounds of phosphoric acid per acre were tested. Low rates of phosphoric acid did not inhibit the normal vegetative growth, although the plants were of a darker green color. High phosphoric acid produced bloom 10 days to 2 weeks earlier than the lower rates with an 80 pound rate of phosphoric acid per acre producing highest yields.

Rates of Potash. From 0 to 310 pounds of potash were applied per acre, derived largely from nitrate of potash and muriate and sulfate of

potash sources. Tests have shown that higher rates of potash may be used successfully and economically. This potash need is generally accentuated on most of the tobacco soils of Florida because, on the average, they have been heavily cropped without much or any additional fertilizer. With low levels of potash, the tobacco plants stop vegetative growth at an early date, and the leaves become rough, crinkled, and reddish-brown spots appear resulting in a poor quality of leaf. Tobacco suckers have been noted to have potash deficiency symptoms, indicating severe potash deficiency. Maturity data show that high levels of potash definitely delay bloom, and this coupled with other elements might be a practical preventive to the immature ripening or rapid yellowing that makes harvesting necessary two or three times weekly.

Fertilizer mixtures such as 3-8-11 and 3-8-16 have given profitable increases over the 3-8-6 analysis. When 4 percent nitrogen and 11 percent potash were used in a formula, yields increased, indicating the possibility of a nitrogen and potash relationship for higher tobacco yields. Chlorine percentage was controlled at the 2% level in all tests.

Rates of calcium. From 0 to 120 pounds of calcium oxide (CaO) per acre were used with no deficiency symptoms noted in any of the tests. An 80 pound rate of calcium per acre produced best results.

Rates of magnesium. Magnesium was tested at rates from 5 to 50 pounds per acre. Magnesium deficiency, commonly known as "sand drown", did not appear in any of the tests. This condition has been noted in some areas of the State, particularly on the soils that have been heavily cropped and had no magnesium supplied in the fertilizer. Applications of from 20 to 35 pounds per acre of magnesium oxide gave best results.

Rates of Sulfur. From 9 to 169 pounds of sulfur per acre were applied with 89 pounds of sulfur trioxide (SO_3) producing best results. Other tests have shown the need for further study on the nitrogen, potash, sulfur ratios.

Rates of chlorine.. From 0 to 40 pounds per acre were tested, with the 20 pound rate producing best results. A heavier rate of 40 pounds per acre produced an undesirable leaf that was very fleshy, glossy green, and curled upward around the edges. Tobacco fertilized with 40 pounds chlorine per acre changed color and was quite easy to get in "high order" after it was cured.

Rates of boron. From 0 to 3 pounds of boron per acre were used in the tests with 0.5 pound of boron per acre producing best results. Three pounds per acre was very toxic, producing small stunted plants with brittle glossy leaves, reddish-brown spots, and the tobacco ripened very slowly, with a resulting poor quality leaf.

Rates and sources of nitrogen. Nitrogen sources and combinations have been one of the caution points in tobacco fertilizer analyses, and with this in mind tests were made using single sources and combinations of sources of nitrogen.

Uninterrupted growth from transplanting to the flowering period is important for general plant growth and vigor, but tobacco quality cannot always be judged by vegetative growth. It is best for the nitrogen supply to begin a gradual decline in the late growing period to insure a uniform

ripening, although as mentioned earlier, a premature yellowing is not desired.

Tests were conducted with nitrate of soda, sulphate of ammonia, urea, cottonseed meal and stable manure. An analysis, having 1/3 nitrate of soda, 1/3 sulphate of ammonia, 1/3 urea or 30 pounds nitrogen per acre, produced best yields followed closely by a combination of 1/2 nitrate of soda, 1/3 sulphate of ammonia, 1/3 urea or 30 pounds nitrogen per acre, gave poor results, although stable manure, 3 percent nitrogen equivalent plus a 3-8-6 complete fertilizer has given outstanding yields over the check 3-8-6 analysis.

Rates of fertilizer and numbers of plants per acre. 1000 to 1800 pounds of the standard 3-8-6 fertilizer per acre was used with 5026 plants per acre, and 1000 to 1800 pounds of the same analysis with a 300 plant increase for every 200 pounds increase in fertilizer per acre.

The following are per acre yield increases from the 1000 to 1800 pound rates when 200 pounds of additional fertilizer were added for each increase, with 5026 plants: 2, 117, 177, and 228 pounds respectively.

The yields per acre when 300 additional plants were added for each 200 pounds increase in fertilizer were: 81, 163, 228, and 282 pounds per acre respectively.

From these tests it seems quite possible for the grower to increase the number of plants in about the same ratio with fertilizer increases for most profitable returns. For example, 1600 pounds of fertilizer and 5926 plants produced the same increased yields as 1800 pounds of fertilizer with 5026 plants.

Acid, basic and neutral mixtures. All treatments were made neutral so far as possible in the formulae test, thus the question of acid, basic and neutral mixed fertilizer for sandy soils. Results of the Neutral Mix were not significant over acid or basic mixes, however, the acid mix did produce a higher quality tobacco than the neutral or the basic mix.

Minor Elements. Tests with copper, manganese, iron, cobalt, zinc and boron did not give an increase in yield over the no minor element treatments and a toxic condition was noted on several treatments.

Varieties. The following varieties of light and heavy types of flue-cured tobacco were tested, Light types: Gold Dollar, Bonanza, Mammoth Gold, Yellow Mammoth, Virginia Bright Leaf, Cash, and 401; heavy types: Adcock, Gold Leaf, Hester. The light types were far superior in quality to the heavy types, although some of the heavy types were comparable in yield. The Cash variety has been a very popular variety in Florida, but because of undesirable genetic traits it has practically been discarded. This is one of the parents of the 401 variety. Any recommendation for the best variety would be difficult when the lighter types are to be recommended, because soil type, culture, and fertilizer practices on individual farms must be considered. Fertilization data do not show any relationship of variety to fertilizer response.

Cultural practices. These may vary from grower to grower, but in tests the standard practice has proved equal to any method yet tried. Irrigation will prove valuable to those that have access to a plentiful water supply.

Climatic conditions. An abundance of healthy plants with good weather conditions at transplanting time, and intermittent showers during the growing season is the ideal for a crop of tobacco. This is not always the case in tobacco production, as oftentimes heavy rainfalls occur during the early growing season which may leach part of the necessary nutrients, whereas delayed rainfall often causes the plants to harden up and with excessive rainfall during the late growing period makes for flash growth, and oftentimes very poor quality. Growers oftentimes could profit by applying additional fertilizer, during the growing season. Adverse weather conditions during harvesting reduces quality. Sunny days should precede harvesting days, if possible—however, this factor is not controllable.

Harvesting. Tobacco should be "topped", which is the removal of the flower, for increased production and quality. Topping usually precedes the actual harvesting of the leaves from the stalk—which is from 10 to 11 weeks after transplanting. Tobacco should be "ripe" before it is primed from the plant. Ripe tobacco has a dull yellow cast and yellow specks begin to occur over the leaf surface. Harvesting is greatly influenced by disease and weather conditions, but an average crop should be harvested not more than once a week. The leaves should be handled carefully during the priming, as they are easily broken and torn, making for reduced quality.

Curing. Curing immediately follows the harvesting, and is one of the most important factors in Bright tobacco culture. Tobacco that has been properly fertilized, cultivated, harvested, and prepared for curing should be easy to cure for maximum quality, although vegetative growth which appears excellent to the eye may not continue to be best when the leaf is cured. Curing may be termed the gradual removal of leaf moisture (80 to 90 percent) by certain temperature advances, at which time certain enzymatic action takes place, producing desirable or undesirable individual leaf characteristics as to color, aroma and elasticity. These temperature changes are known as (1) Yellowing, (2) Fixing the color, (3) Drying leaf and stem. Thus, it is very easy to reduce a good leaf to a poor quality by improper regulation of the temperature and ventilation during the curing process.

Leaf quality. High yield and good quality is the goal in any tobacco crop, but like grades should be classed together for best returns, which has not been the rule for the last several crop seasons.

Briefly summarized. If one is to be successful as a tobacco grower, it is necessary to keep cost and labor at a minimum, have a working knowledge of the many related phases of crop production; namely, soils, fertilization, pathology, and entomology, as well as experience, which is also important and necessary for many crops.

GRAZING CARPET AND COMMON BAHIA GRASS ON FLATWOODS LAND

DR. E. M. HODGES AND DR. W. G. KIRK *

Pasture areas for experimental grazing were established at the Range Cattle Station during the spring and summer of 1942.

The native land, covered with wiregrass and palmetto, was thoroughly disced and chopped to destroy the native vegetation. Immokalee fine sand, a typical flatwoods soil, made up almost all of the area involved. This soil is relatively low in natural fertility and has an average pH of 4.2 before treatment. Drainage is good except during periods of heavy rainfall.

All original fertilizer and lime materials were applied after land preparation and prior to seeding. Subsequent soil amendments have been applied to the surface. Annual maintenance has been given, using either a mower or a chopper with closely spaced blades.

Yearling and 2-year-old steers have grazed on the pastures during the 1943, 1944, and 1945 seasons. The animals are rotated between duplicate pastures at approximately weekly intervals, the same individuals grazing on the same species-fertilizer combination through the entire season. Management has been intended to obtain the greatest animal gain per acre.

TABLE 1.—WEIGHT CHANGES AND MINERAL CONSUMPTION OF STEERS ON FLATWOODS PASTURES.

(Three-year average)

CARPET GRASS	Beef Gain Per Acre, per Season	Average Daily Gain	Mineral Consumption per Animal per Day
	Pounds	Pounds	Pounds
No fertilizer	11	0.30	0.33
Pr[1]	37	0.55	0.20
NPs K[2] Ca[3]	61	0.72	0.14
NPr[1] K[4] Ca	78	0.87	0.11
NPs K Ca ME[5]	86	0.74	0.10
COMMON BAHIA GRASS			
No fertilizer	25	0.72	0.20
NPs K Ca	66	0.77	0.16

[1] Pr—finely ground raw rock phosphate at 1800 lbs. per acre, 1942.

[2] 400 lbs. per acre of 3-16-8 in 1942; 100 lbs. nitrate of soda in 1943 and 1944; 500 lbs. of 6-6-6 in 1945.

[3] Hicalcic lime applied at 2000 lbs. per acre, 1942.

[4] N and K applied at same rates as in footnote 2.

[5] Rates per acre—iron, manganese and magnesium sulphate; 50 lbs. each—copper sulphate; 25 lbs.—borax; 10 lbs.—zinc sulphate; 10 lbs.—cobalt chloride; 1 lb., 1942.

* Associate Agronomist and Vice-Director in Charge, respectively, Range Cattle Station, Ona.

Grazing results for Carpet grass under 5 different fertilization practices and Common Bahia at 2 fertilizer levels are indicated in Table 1.

Gain per acre is the weight increase attributed to a single acre of pasture for a spring and summer grazing period of about 7 months duration. The average daily gain represents the weight increase per day for each animal over the entire grazing season. Average mineral consumption includes the amounts of common salt, steamed bone meal, and salt-sick supplement taken by each animal for each day on the pasture. Animals had free access to these minerals.

Unfertilized carpet grass established slowly and produced low gains while mineral supplement consumption on this pasture was high. Two animals grazed on 10 acres of unfertilized pasture made a net loss for the 1944 season, accounting for the low average gains as seen in the Table.

Raw rock phosphate applied at 1800 pounds per acre increased the beef gains and reduced mineral supplement consumption. Animals grazed on pasture getting this treatment finished the grazing season with a higher market grade than those on the untreated grass.

Carpet grass grew more rapidly on limed and fertilized land than on the two preceding treatments. This resulted in more gain per acre and in distinct improvement in the grade of beef produced. A further change in the mineral nutrition of the animal is indicated by the reduction in mineral supplement consumption.

The substitution of a heavy rate of raw rock phosphate for the superphosphate in the complete fertilizer and lime has given some increase in beef yields and a reduction in mineral consumption. This comparison is only begun and cannot be evaluated until the effect of the refertilization program is obtained.

The use of copper, zinc, manganese and other minor elements in addition to the N-Ps-K-Ca treatment yielded a substantial increase in gain per acre. More cattle have been grazed on the minor element treated pastures, but there is little indication that the individual animals have thrived better than those on the no minor element pasture.

Common Bahia grass planted and replanted on unfertilized land has produced no stand after 4 years time. The addition of lime and complete fertilizer encouraged growth of this species, although a complete stand has not yet been obtained.

Comparing the yield of untreated Carpet and Bahia grass, the record shows an advantage for the Bahia. The small number of animals used permits variations between animals to influence the results over a short period of years. At this low fertility level, small variations in natural productivity may cause large differences in the grazing results.

Fertilized Bahia withstood the drought of early 1945 which seriously reduced the stand of Carpet grass. As a result of this drought resistance, the average performance of the Bahia has been a little better than Carpet in the Range Station trials.

These observations seem sufficient basis on which to discourage extensive preparation and planting of pasture on this type of land without fertilization. They may also serve to indicate that the question of money return from fertilized pasture is not completely answered and that it is to be treated with utmost caution by all concerned.

SYMPOSIUM III: THE USE OF LIME IN FLORIDA AGRICULTURE

Newell Hall, Saturday, February 15, 1946

9:30 A. M.

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INTRODUCTION

Dr. F. B. Smith *

The use of lime on Florida farms increased from 3,500 tons in 1930 to 121,200 tons in 1943. This increased use of lime in agriculture has not been confined to Florida and the Southeast but similar increases have been recorded for eastern and north central regions of the United States. It has been estimated that 60 per cent of this increased use of lime was due to distribution and benefit payments by the Agricultural Adjustment Administration. A contributing factor to the increased use of lime in recent years, no doubt, has been the increase in scientific knowledge and understanding of base exchange reactions in soils together with the development of methods for determining the lime requirements of soils. It is not claimed that the practice has recently been accepted as fundamental and necessary, but the well informed have long known that liming acid soils is basic to permanent agriculture in humid regions.

During the early days of the depression it was not uncommon to hear the question, "Why lime acid soils?" "Why not breed acid-tolerant crops?" Of course those who understand the principles of soil formation and soil fertility maintenance know that an "acid agriculture" is fundamentally unsound. A simple illustration of soil genesis makes this clear. The clay minerals are formed by the hydrolysis of primary minerals such as muscovite, biotite and orthoclase. The presence of water is a necessary condition and the speed of the reaction is increased by carbon dioxide and by an increase in temperature. The removal of the soluble products is assumed under humid conditions. The net result is a de-alkalization of the original mineral and a progressively increased acid reaction until ultimately the secondary mineral which was formed may be dissolved, leaving silicon dioxide and iron oxide. The process has already progressed far in this direction in some of our humid, tropical soils. In other words, the point is made that a certain base status is necessary if we are to keep the soils after nature has formed them. Carried to its logical conclusion, an acid agriculture would result in the dissolution of the soil from under our crops. However, we should be forced to quit growing plants long before that because of unfavorable physical conditions of the soil, the unavailability of essential elements, or the presence of toxic concentrations of iron and aluminum. Even before these conditions could appear, unfavorable micro-

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* Chemist, Soils Department, Florida Agricultural Experiment Station, Gainesville.

biological conditions and the competition of uneconomic species of plants would preclude the possibility of productive farming.

When soils are first formed they contain more or less of the bases. Through the processes of soil genesis much of the base content of the original material is lost. This loss of bases is greatly intensified in regions of high rainfall by the presence of carbon dioxide. In addition to this loss by leaching, certain bases are removed in plants where crops are harvested. Consequently, soils naturally become increasingly more and more acid as time goes on. In time, then, all soils will become depleted of their bases unless the process of removal is checked or additions of bases are made. Lime is fundamental in good soil management and necessary in the maintenance of permanent soil fertility. However, one should not be alarmed if the soils are slightly acid. As a matter of fact, nearly all life prefers a slightly acid medium in which to develop. On the other hand, it is a common observation that the highly productive soils of the world are well supplied with bases. That is, they are not strongly acid, but the colloidal complex has a high base status. This observation is so common that many of our specialists have concluded that all soils should be limed. Now it should be obvious that all soils are not alike and successful soil management calls for adjusting conditions to meet individual soil needs. Sometimes this is a difficult task and small wonder that serious injury has often resulted from the use of too much lime. If most plants prefer an acid condition and injury from over-liming may result, then why is it necessary to control the acidity of the soil by the use of lime? In the first place, calcium is an essential element and strongly acid soils may mean a deficiency of available calcium. Some crops have a low lime requirement and even under acid soil conditions may find sufficient available calcium for their needs.

In addition to supplying the nutrient element calcium, lime has a number of other important functions in soils. Calcium is a requisite for the aggregation of colloidal particles whether organic or inorganic. These particles are dispersed under acid soil conditions and under the impact of heavy rainfall they are carried down to form a hardpan layer. The movement of air and water so necessary for good plant growth are impeded and soil fertility is impaired. The effect may be more noticeable in heavy textured soils, especially on slopes where erosion may be accelerated, but it is none the less important in sandy soils where every colloidal particle is virtually worth its weight in gold.

Lime on acid soils increases the availability of the essential nutrient plant food elements. A general review of the literature shows that one beneficial effect of lime is in the releasing of highly insoluble phosphates. In strongly acid, heavy textured soils the phosphorus exists in the unavailable iron and aluminum combination. Consequently, applications of lime usually result in an increased uptake of phosphorus and calcium by the plant. The effect of lime on the pH of the soil depends on the mechanical composition of the soil, the nature of the exchange complex, and amount of calcium already absorbed. Calcium in the soil sufficient to produce pH values of 5.8 to 6.4 usually results in increased availability of all the essential elements. Potassium, magnesium, the minor elements, and phosphorus in sands, added to strongly acid soils leach readily and in sandy soils under

heavy rainfall, crops may suffer a deficiency of these elements even with heavy fertilization. Where removal by leaching is not effected, toxic concentrations of aluminum, manganese or other elements may occur.

Good soil management calls for an understanding of crop needs as well as of soil conditions. The problem of proper liming becomes one of adjusting the pH to meet the needs when they are known. This is not quite so simple as it may appear to be. The soil is a product of natural forces, such as climate, parent material and vegetation, acting over a very long period of time. A product so long in the forming has rather fixed characteristics and they are not easily changed without radically affecting the whole constitution of the soil. The pH of the soil is seldom ever adjusted downward. However, this may be desirable under certain conditions. It is to be remembered that fertile soils are usually supplied with an abundance of bases and acid conditions mean a lack of bases. Sometimes it is desirable to lower the pH of the soil to a rather low value temporarily, as in the case of controlling Brown Rot of potato. After the pH has been adjusted downward for a short time, sufficient lime should be added to readjust the pH to a normal value. The pH should never be adjusted far downward and allowed to remain low for an extended period of time. This does not, of course, refer to azaleas or other permanent plantings where the adjustment is localized. Sulfur is one of the best materials for producing soil acidity because it does not leave harmful residues and the action is relatively mild. The continued use of ammonium sulfate causes the soil to become acid. The decomposition of nitrogenous plant materials, such as cottonseed meal, results in acid production through nitrification and a lower pH. Aluminum sulfate and iron sulfate are often recommended, aluminum sulfate especially for azaleas.

The determination of the amount of lime to apply to raise the pH a given amount or the determination of the amount of sulfur to apply to lower the pH a given amount is a difficult problem and varies between soil types, and even within a soil type depending upon the organic matter content. The earlier practice was to recommend enough lime to neutralize the total acidity. Where sufficient lime is applied to correct the total acidity, pH values of 8.0 and above are common. Sufficient lime to correct total acidity may have detrimental effects, usually referred to as over-liming injury. The injury is not permanent but serious, and because of that it has served to prejudice many against the use of lime under any condition. One must consider the total exchange capacity of the soil, the pH and the ratio of calcium to other bases in order to arrive at the true lime requirement of the soil. There is a relationship between the three values for a given soil, but this relationship may not be the same for different soils. The pH, alone, is not a safe guide but if one knows the conditions of the soil and the needs of the crop, the pH value is a good index of the lime needs of the soil.

THE USE OF LIME IN FLORIDA AGRICULTURE — VEGETABLE CROPS

Dr. F. S. Jamison *

The history of liming for truck crops was reviewed and particular emphasis placed on the need for definite information on the reaction (pH) of the soil or soils of a definite field or area before specific liming recommendations can be made for a particular crop. Serious damage done to light sandy soils in the past by overliming, damages that are expensive and time-consuming to correct, were referred to as the ever-present danger of proceeding on a liming program without adequate information. No formal manuscript to cover this phase of the general discussion was provided. Ed.

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* Truck Crop Horticulturist, Florida Agricultural Experiment Station, Gainesville.

THE USE OF LIME IN FLORIDA AGRICULTURE — CITRUS

Dr. Vernon C. Jamison *

It should be understood that the term "lime" as used here in connection with citrus in Florida refers more to dolomite than to calcic lime. Because of the magnesium released in acid soils from dolomite and because of the importance of magnesium in citrus culture in Florida, dolomite is the most widely used liming material for citrus in this State.

The study of the effect of lime or dolomite or fertilizers upon the sandy soils of Florida is complicated by the unstable condition of these soils with regard to their content of exchangeable bases. Due to the effects of leaching the results found following a soil treatment will depend quite largely upon the length of time and weather conditions since the treatment was applied (Table 1). Where seasonal comparisons are to be made samples should be taken at the same time each year, preferably just before the "spring fertilization" (usually in February). Marked differences are often observed in the nutrient bases, calcium, magnesium and potassium, present in the soil samples taken in different years or seasons of the same year. The variations are attributable to the extent to which the soil was leached during the period between the application of fertilizer and the taking of the soil samples. This is a very important point to keep in mind in connection with soil studies. The results found will give some idea as to the nutrient status at the time of sampling only and they do not necessarily reflect the average soil condition during any given period. If one wishes to follow those changes samples must be taken frequently—at least once each month during fall, winter and spring months and more frequently during the summer rainy period. For this reason data given in this paper should be considered mostly in the light of results for soil samples taken from plots at the same time. That is, as far as the effects of soil treatments are concerned, the differences found at the same sampling dates are of far greater significance than the changes which may be shown by infrequent sampling.

Since the acid colloids in soils will react with liming materials to release the bases or metallic cations to the soluble and exchangeable states advantage is taken of the acid condition of unlimed sandy soils in citrus groves to release magnesium from dolomite, thus supplementing the magnesium used in the balanced citrus fertilizers used. Thus, dolomite is a cheap source of readily available magnesium when used on sour soils. However, as the soil acids are neutralized or nearly so, further additions of dolomite may not be attended with a sufficient release of magnesium to adequately supplement that supplied in the fertilizer and in order to avoid loss in crop production water soluble magnesium or magnesium source materials sufficiently active to release soluble magnesium must be increased in the fertilizer used.

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* Soils Chemist, Citrus Experiment Station, Lake Alfred.

TABLE 1.—THE VARIATION FOUND IN CHEMICAL COMPOSITION OF THE SOIL IN EXPERIMENTAL PLOTS IN RELATION TO RAINFALL OVER A PERIOD OF FOUR MONTHS.

Sample No.	Plot No.*	Date Sampled	Inches Total Rain-fall**	Pounds per Acre-6-inches Exchangeable Bases		
				Ca	Mg	K
3K	M-4	2/7/42	0.0	564	47	86
9K	M-4	2/27/42	3.5	511	40	48
14K	M-4	3/19/42	9.3	595	44	49
19K	M-4	4/2/42	12.5	405	32	46
24K	M-4	6/5/42	15.7	373	26	46
28K	M-4	6/12/42	20.0	341	24	28

* Experimental plots in Block X, Citrus Experiment Station grove, Lake Alfred, Florida.

** Total amount after start of experiment.

Soil acidity is not only important in regards to the release of bases from dolomite applied but it is related to the retention of nutrient cations from the fertilizers applied and also the retention of exchangeable cations against leaching. Nutrient cations supplied in fertilizer are retained better against leaching in a mildly acid than in a very acid, neutral or alkaline soil (3,4,6,7,9). However, after the soluble fertilizer salts are leached from the soil, the nutrient bases held in the exchangeable form are hydrolized and lost more rapidly from the less acid soils. Where excess basic residues are present from overliming the loss is further increased. The over-all effect is that moderate applications of dolomite or lime seems to conserve magnesium added in fertilizer (Table 2), but there appears to be little effect upon the retention of potassium. In addition to the effect upon the retention of exchangeable bases, excessive application of liming materials decreases the activity of copper, zinc, and manganese in the soil solution (5,8,10). Copper and zinc become increasingly difficultly exchangeable with increase in soil pH while it appears that manganese reverts to the hydrated dioxide and then to the inert dioxide form. For these various reasons it has been recommended that the soil pH in citrus groves be controlled roughly between the limits of 5.3 and 6.0 (2).

The materials in the fertilizer as well as the liming materials used are factors in determining the exchangeable bases retained in the soil. One may think that with no regard to the fertilizer used that the kind of lime used will determine the bases that are "built into" the soil. Actually the two are related. The exchangeable bases, or more correctly, the exchangeable cations including hydrogen, are retained in the soil with different degrees of force. The capacity of a given soil to retain these cations (hydrogen, calcium, magnesium, potassium, manganese, and others) is not only limited according to the inherent fertility of the soil, but there is a definite order of attractive force or affinity of the soil for the various cations. That is, hydrogen has by far the greatest affinity for a place in the soil colloidal exchange complex or mechanism with the basic cations falling in the following order of decreasing affinity, calcium, magnesium, potassium, ammonium, and sodium with copper, zinc, and manganese probably falling in order between hydrogen and calcium. This prin-

TABLE 2.—THE EFFECT OF MODERATE APPLICATIONS OF CALCIC LIME UPON THE RETENTION OF MAGNESIUM AND POTASSIUM IN THE EXCHANGEABLE FORM IN THE SOIL FROM FERTILIZER APPLIED.

Date of Sampling	Experimental Block IX			
	Plot 4 Limed (pH 5, 8-6, 2)*		Plot 5 Unlimed (pH 4, 8-5, 2)*	
	Mg	K	Mg	K
12/1/37	0**	32	0**	32
11/19/39	22	43	18	37
1/29/41	48	56	33	70
2/5/42	44	58	29	64
2/3/43	73	74	42	62
3/16/44	45	52	29	51
2/8/45	47	90	37	92

* The same fertilizer treatment carrying 4 percent MgO, the only difference being in the application of lime.

** Before the application of any magnesium to the soil.

ciple is demonstrated in Tables 2 and 3. When calcium carbonate was used to increase the pH of the soil and magnesium added in the fertilizer (equivalent in amount to 4 percent MgO) a little more magnesium was retained in the limed than in the unlimed soil. Thus, magnesium can compete with calcium more readily than with hydrogen for a position in the soil complex. When the soil was limed with a basic magnesium material and calcium was added in the fertilizer (in the superphosphate salts) large increases in exchangeable calcium accompanied the increase in exchangeable magnesium. That is the soil hydrogen was neutralized by the basic magnesium carbonate, and the liberated magnesium replaced the neutralized hydrogen, but calcium readily replaced a portion of the magnesium. Thus, one may temporarily introduce easily exchangeable cations into soil by adding them in basic materials but they may be rapidly replaced by other cations, especially hydrogen and calcium. Pot lysimeter tests conducted at the Citrus Experiment Station have shown that although fairly large amounts of potassium may be introduced into the soil exchange mechanism, it is quickly replaced and lost by leaching when a complete fertilizer (containing calcium and magnesium salts) is added, especially if the fertilizer is "physiologically acid" (i.e., causes the soil to become increasingly acid).

Finally, there is one other principle sometimes ignored or misunderstood that is important as far as the effect of the quantities of nutrient cations in the soil upon the composition of citrus foliage is concerned. The magnesium absorbed by citrus from a soil high in exchangeable magnesium may be comparatively lower than that absorbed from a soil low in exchangeable magnesium (Table 4). In a survey of groves on the ridge in comparison with those in the coastal sections of the State it was found that the magnesium in the foliage of hammock groves of the coast averaged slightly less than it did on the ridge even though the hammock soils contained, on an average, nearly four times as much exchangeable magnesium (1). In the paper given by Dr. B. R. Fudge previously during these pro-

TABLE 3.—THE EFFECT OF MAGNESIUM CARBONATE SOIL APPLICATIONS UPON THE RETENTION OF EXCHANGEABLE CALCIUM AND POTASSIUM DERIVED FROM FERTILIZER APPLICATIONS AND UPON SOIL pH AND EXCHANGEABLE MAGNESIUM IN THE SOIL.

Plot Number		X-F-1				X-F-3				X-F-6			
Lbs. $MgCO_3$/acre/year		None				400				600			
	Date Sampled	Soil pH	Exchangeable Bases Ca	Mg	K	Soil pH	Exchangeable Bases Ca	Mg	K	Soil pH	Exchangeable Bases Ca	Mg	K
Analytical Results	1/21/38	4.99	278	9	54	5.39	287	62	47	6.71	309	232	61
	2/13/39	4.80	307	12	36	5.05	352	78	93	6.65	339	381	88
	2/5/40	4.99	290	8	67	5.51	405	55	82	7.09	420	268	66
	1/8/41	4.76	300	13	49	5.64	485	105	58	7.70	544	443	44

ceedings it was shown that the balance between the various cations largely controls the quantities absorbed as shown by foliage composition. Thus, a soil high in exchangeable calcium may have an inadequate supply of magnesium, especially if the quantity found were just sufficient to allow adequate absorption in a soil of low calcium content. It is quite clear that not only the absolute quantities of the soil nutrients should be considered but the relative amounts or the balance between the quantities present in the soil when soil analytical data are being compared.

TABLE 4.—THE COMPARISON OF THE AVERAGE SOIL AND FOLIAGE COMPOSITION OF SOIL AND FOLIAGE AS FOUND IN A SURVEY OF GROVES ON WIDELY DIFFERENT SOIL TYPES.

Soil	Exchangeable Bases Pounds per Acre-6-Inches of Soil		
	Ca	Mg	K
Hammock	3600	291	168
Sandy	764	54	99
Foliage	**Percent of Dry Matter**		
	Ca	Mg	K
Hammock Soil Groves	5.61	0.318	1.36
Sandy Soil Groves	3.09	0.336	2.26

From the practical point of view, the moderate use of dolomite on acid soils in Florida devoted to citrus is beneficial in that dolomite is a cheap source of magnesium and exchangeable nutrient cations are conserved against leaching a little better in a mildly acid than in a strongly acid soil. However, since magnesium is released very slowly from dolomite in a mildly acid, neutral or alkaline soil and readily exchangeable bases such as potash are lost more rapidly in the presence of basic residues after the soluble salts are leached and nutrients like copper, zinc and manganese become less active as the soil pH increases, it is quite clear that precautions should be taken to avoid excessive applications of dolomite or lime. As previously recommended, the soil pH in citrus groves should be kept above 5.3 and should not be carried above 6.0 with dolomite applications. Light annual applications are preferred to those which are heavier but less frequent.

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THE USE OF LIME IN FLORIDA AGRICULTURE — FIELD CROPS

Dr. Henry C. Harris *

Apparently I had the wrong idea of what this discussion was to be. I thought practical recommendations for the various crops were to be taken up in an informal way, and for that reason I prepared some remarks to the effect that the amount of lime for field crops would depend on the soil and the crop. Acid soil would need lime but soils well supplied with lime would not. Furthermore many crops such as corn and cotton were not usually limed while clovers and legumes were. But this did not seem to be what I was to talk about and when the Chairman called for the formal papers discussing the more technical aspects of the subject I decided to throw my prepared paper away and discuss a few points which interest me about pH values of soils.

Other speakers have mentioned the fact, and I want to emphasize it, that the pH value of the soil on any one plot is by no means constant throughout the year. The same plot may vary from time to time, and it is almost impossible to control a soil at an exact pH value. By means of such substances as lime and sulfur, one can secure a general control of the pH value of the soil, which is quite valuable in experimental work, but there frequently are fluctuations in the value for the same spot at different sampling periods.

This leads me to the observation that there is no value in pH, per se, except insofar as it gives an indication of the nutritional condition of the soil. Plant physiologists have conducted experiments in which the pH value of the nutrient solution was controlled over a range from about 4 to about 9 and there was little effect of the change in pH value over the whole range when the plants were well supplied with nutrients. Apparently the bad or good effects of any change in pH value is quite largely related to the change in nutrition.

In this connection I want to mention two soil situations in this State. Many of our sandy soils are acid, and need some lime, but the base exchange capacity is very low, and it does not take much lime to saturate them. If large amounts of lime are applied the pH becomes high and one gets into such disturbances as unavailability of minor elements. Under such conditions an effort is made to apply enough lime to bring the pH value of the soil to about 6 or a little above. One tries to apply enough lime to do that, and yet not enough to get into these other troubles. The problem, therefore, is one of nutrition and not the pH value, except, as it relates to nutrition.

Around Homestead, Florida, are some unusual soils. I am told that they may be 90% limestone and should be overlimed. The pH values of them are very high. There is so much lime in the soil that one would expect crops to do poorly, and yet excellent crops are grown. As I understand it the only minor element that has given much response is manganese. In this situation a high pH value apparently has done no harm. Now why

* Associate Agronomist, Florida Agricultural Experiment Station, Gainesville.

is that? I do not know the full answer, but I suspect that there is something about the nature of the soil, and, or, the amount of organic matter so that a good supply of available nutrients is maintained for the crops.

The two soil situations are quite different. In one case a high pH value is harmful; in the other the existing high pH value seems to do no harm. This illustrates perfectly the point that I am trying to make, namely, that the pH value of the soil is not the important thing, but it is the supply of available nutrients for the crop.

THE USE OF LIME ON FLORIDA PASTURES

Dr. G. B. Killinger *

According to AAA payments there were 60,654 tons of agricultural lime used on Florida farms in 1944. Of this tonnage it is estimated that 19,783 tons were applied to pastures. It is recognized that a greater total tonnage than that mentioned was actually used as the tonnage indicated was used in qualifying for AAA payments. Probably the ratio of total lime used in the State to the amount applied to pastures is the same, or about 1 out of every 3 tons.

Lime increases the calcium content of various grasses growing on the acid soils in Florida. For example, Carpet grass on a Leon soil with original pH of 4.25, when limed with 1 ton of high calcic lime may have an increased calcium content of from 25% to 50%. This higher content of calcium in herbage is highly important in body and bone building processes.

Most grasses do not require additional lime for growth, however, Bermuda grass is an exception. Bermuda grass will grow and produce very sparsely on acid soils that have not been fortified with lime.

CLOVERS

The "Trifolium" clovers require, usually, from 1 ton upwards of lime on acid soils. The "Medicago" clovers require, usually, 2 or more tons of lime for best growth on acid soils. Particularly is this true with the Black medic and Sweet clovers.

LESPEDEZA

The various lespedezas are not demanding of lime, but respond to moderate applications of ½ to 1 ton per acre.

OVER-LIMING

Heavy applications of lime, from 3 tons per acre upward, may cause deficiencies in other plant food elements on some Florida soils. With heavy lime applications, and when legumes are to be grown, potassium should be supplied in liberal amounts, likewise manganese may become deficient in such instances.

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* Agronomist, Florida Agricultural Experiment Station, Gainesville.

BANQUET AND BUSINESS MEETING

PROF. W. E. STOKES, Presiding

The usual business meeting was called at 9:00 P. M. immediately following the Annual Banquet held in Hotel Thomas, Gainesville, on the evening of February 15. The reading of the minutes was dispensed with and the first order of business was a most inspiring lecture by Dr. Selman A. Waksman, Microbiologist, Rutgers University, New Brunswick, New Jersey, on "Soil Microbes and Medicine." The complete text of his lecture is published at the front of the volume, pp. 7-17, where Dr. Waksman is acknowledged as Guest Speaker of the evening.

APPOINTMENT OF NOMINATING COMMITTEE

A Nominating Committee was appointed by the Chair at the close of the morning meeting and charged with the responsibility of reporting its recommendations in the course of the Business Meeting. The Committee was made up as follows:

Dr. F. B. Smith, *Chairman*
Mr. H. A. Bestor
Mr. R. A. Carrigan

APPOINTMENT OF AUDITING COMMITTEE

The Chair appointed the following Auditing Committee to assist the Treasurer in auditing the accounts of the Society as of the close of the year with authority to approve same if all records were found in order:

Dr. Roy A. Bair
Mr. Charles C. Seale
Dr. W. T. Forsee, Jr.

REPORTS OF SUBJECT MATTER COMMITTEES

Brief extemporaneous reports were made by the Chairman of the Forest Relationships Committee and of the Animal Relationships Committee which were very interesting but not sufficiently of record to be published. There were comments in the course of the brief discussion that followed suggesting that these Committees should be more active and more systematic in their reports in the future.

RESOLUTIONS COMMITTEE

Mr. Luther Jones, *Chairman*
Dr. F. B. Smith, *Acting Chairman*

There was a considerable amount of discussion regarding the merits of the Abernethy Bill, which was about to come up again for congressional action at the time of the Annual Meeting, especially as a vehicle for the support of our much needed help in Central and South Florida in con-

nection with water control and conservation. No instructions were given the Committee to prepare a resolution on the subject.

The Resolutions Committee was instructed by the Chair to prepare an appropriate resolution of sympathy to send to the immediate relatives of those members of the Society who have been taken by death during the year.

ELECTION OF OFFICERS

The Nominating Committee was requested to report upon their recommendations for candidates to fill the office of Vice-President of the Society and offered a single candidate in the person of Mr. Horace Bestor, Drainage Engineer of Clewiston, in view of the outstanding work he has done in the field of water conservation in Florida. Simultaneously with the recommendation the Chairman of the Nominating Committee moved that nominations be closed and the Secretary instructed to cast a unanimous ballot for the Committee's nominee. The motion carried unanimously.

INSTALLATION OF OFFICERS

Following the election of the Vice-President for the coming year and in the absence of the incoming President, Dr. Herman Gunter, Prof. W. E. Stokes welcomed the new Vice-President and recognized the place which automatically became his, as immediate Past President, on the Executive Committee.

MEETING OF THE EXECUTIVE COMMITTEE

Prof. W. E. Stokes, Presiding

In the absence of Dr. Herman Gunter, the incoming President of the Society, Prof. W. E. Stokes presided at a very brief meeting of the Executive Committee at which the first and practically the only item of business was the naming of Dr. R. V. Allison to continue as Secretary-Treasurer of the Society for another year.

The place of the next meeting was discussed but no definite decision was arrived at. South Florida was strongly recommended and the inclusion of a well-rounded discussion of fiber crops in Florida was urged as an excellent possibility for a part of the program.

RESOLUTIONS

Soil Science Society of Florida

RESOLUTION OF SYMPATHY

Whereas, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence felt for a long time to come,

Now, Therefore, Be It Resolved, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each:

Dr. L. R. Jones
Madison, Wisconsin
Brookfield, Vermont
Orlando, Florida

Mr. Geo. M. Rommel
Bradenton, Florida

Col. B. F. Floyd
Davenport, Florida

Mr. F. E. Bryant
Palm Beach and
Azucar, Florida

Mr. Rudolph Weaver
Gainesville, Florida

By the Resolutions Committee
Dr. F. B. Smith, *Acting Chairman*

Gainesville, Florida
February 15, 1946

W. E. STOKES

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Gainesville

Herman Gunter .... Vice-President
Tallahassee

G. M. Volk .... Member Executive Committee
Gainesville

R. V. Allison .... Secretary-Treasurer
Belle Glade

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